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ABSTRACTS—*continued.*

JOURNAL

OF THE

Institution of Electrical Engineers.

Founded 1871. *Incorporated* 1883.

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The Two Hundred and Fifty-seventh Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, January 11th, 1894 — Mr. W. H. PREECE, C.B., F.R.S., late President, in the Chair.

The minutes of the Annual General Meeting of December 14th, 1893, were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

William Ashcombe Chamen.
J. Irving Courtenay.
A. J. Lawson.
R. Hodgshon Postlethwaite.
H. Faraday Proctor.
David Urquhart.
Francis Fane Yeatman.

From the class of Students to that of Foreign Members —

Nai Kl:em.

From the class of Students to that of Associates—

Walter James Bache.	Wilmot Ernest Lane.
Charles Proctor Banham.	John Mackenna.
William Walter Borman.	Frederic Charles McQuown.
William M. Carver.	John T. Morris.
Harry C. Channon.	G. Dudley Aspinall Parr.
William Findlay.	E. Salthouse.
William Holmes.	Sydney Cummins Smith.

Mr. H. Human and Mr. J. O. Girdlestone were appointed scrutineers of the ballot for the election of new members.

The CHAIRMAN: Ladies and gentlemen,—it is a great pleasure to us to see that our meeting is graced by the presence of some ladies—nearly the last duty that the retiring President has to perform is the agreeable one of presenting the premiums to those to whom they have been awarded by the Council. The first is the "Institution Premium," value £20, awarded to Mr. W. B. Sayers. Mr. Sayers, I have very great pleasure in presenting to you quite a small library. I am told you have selected the books yourself. I can assure you that the Council, and every member of this Institution, is very happy indeed in presenting to you a premium for one of the most admirable papers we have had here for a very long time. I may also tell you that your paper has created quite as much interest—and I may even say, as much sensation—in the United States as it has in this country.

The next premium is the "Students' Premium," awarded to Mr. W. R. Cooper. I have great pleasure in presenting you, Mr. Cooper, with a smaller library; but at the same time I daresay it contains just as much knowledge as the larger library presented to Mr. Sayers. At any rate, I hope you will direct your attention to digesting the contents of these books, with the same benefit that I am sure Mr. Sayers will experience from the study of his greater number. I may tell you that there are many members of this Institution who would only have been too pleased to have written the admirable paper on "Primary Batteries" that you wrote.

Now, ladies and gentlemen, I have a final and very pleasant duty indeed to perform I have to resign this chair, and metaphorically to transfer the chain of office, which you must imagine is now upon my shoulders, to the shoulders of one much more worthy to discharge its duty than I have proved myself to be. I am quite certain that there is no one that we should be more pleased or more proud to see in this chair than the one who bears the name of our first President, and, I may add, who bears the name of the most remarkable and most distinguished engineering family that ever existed in this world. Mr. Alexander Siemens, I resign my chair to you with great pleasure to myself, and I hope with the same satisfaction to you; and I hope through the ensuing year you will receive the same support that I have done from the Institution of Electrical Engineers.

Mr., Alexander Siemens, the new President, then took the chair.

Sir DAVID SALOMONS: Mr. President, ladies and gentlemen,—It is not often Mr. Preece makes a mistake. He stated to you just now that the last function he had to perform was handing the premiums to those gentlemen who had earned them; but Mr. Preece will be called upon in a few minutes to speak again, and I trust not for the last time here. It is my pleasant duty to move a vote of thanks to Mr. Preece, and in doing so I need scarcely tell you that he is a gentleman—one of the very few to be found in the world—with whom no one could quarrel. I do not mean that he is one of those weak, good-natured men sometimes met with. He is a man of strong character. He presides in the Council room as a chairman should do. When he lays down the law, it is obeyed on the spot. No one ever desires to dispute his authority, even when a difference of opinion arises; and in this hall he is as much respected as he is in the Council room. After serving his country for many a long year, and serving this Institution from its very beginning, he has at last been rewarded—with a small mark, it is true: it is but a few pennyworths of ribbon with a little medal strung upon it, but at the same time it carries with it great weight. It shows the high appreciation which the Queen and the Government of this country have of

his talents, and of the services which he has rendered to the State. Those present to-night have the opportunity to congratulate him most heartily that such an acknowledgment has been made of his great services to the country and the electrical profession. We hope, therefore, that in time to come he will gain greater distinction, as I am sure he will; and, seeing that he is now in the prime of life, and in the best of health, let us trust that he may live to acquire all those distinctions which, though of no value in themselves, show the esteem in which a man is held by his fellow-countrymen. Last year Mr. Preece went to America, and, as our President, upheld our honour at Chicago. For that alone our thanks are due to him. But they are also largely due from this Institution, where he is known personally to every member, not merely from the fact that he accepted the Presidency for the second time, at great inconvenience, since it necessitated giving up a large share of his valuable time to our service, but also for the goodwill he has shown to every member, down to the youngest. I am quite sure you will accord him with acclamation a hearty vote of thanks, showing thereby that we really feel in our hearts what we utter with our voice and show by outward expressions.

Mr. CROMPTON: I rise to second the motion which has been so eloquently put before you by Sir David Salomons. I feel that I can add little to intensify the feeling that Sir David has roused by his eloquent remarks. Most of us here know how much this Institution is indebted to Mr. Preece, who took a very prominent part in first turning the thoughts of the original members of the Society of Telegraph Engineers into the new channel of modern electrical engineering. I know that in my own case he was the principal cause of my joining the Institution, and I believe that many other gentlemen in the room can say the same. Mr. Preece has been a good friend to many here, and I think that there is no vote in which we can all join in so heartfelt a manner as in this vote of thanks to our Past-President, who I hope will live long enough to possibly take a third term of office.

Mr. PREECE: Mr. President,—I could very easily have proved to Sir David Salomons that he was wrong, for on one occasion,

after a great many speeches had been made, I was called upon to make another speech, and my other speech was simply dumb show. I bowed, and I moved my hands, and Sir Frederick Bramwell, whose wit you all know, said that that was the very best speech I ever made in my life. So on this occasion there was no actual necessity for your hearing my voice again this evening, for I might simply have risen from my chair and bowed. The only reason why I do now speak is because, at any rate, I do get some respect up here, if I do not downstairs; and, secondly, that I think it is only just, fair, and right that I should acknowledge the kindness with which you have received the words that have fallen from the lips of Sir David Salomons and Mr. Crompton, and also thank you heartily for your recognition, not only of the services that I have endeavoured to perform in my capacity of President of the Institution during the past 12 months, but also for your congratulations upon the honour that is about to be bestowed upon me by Her Majesty the Queen.

The PRESIDENT then delivered his Address.

INAUGURAL ADDRESS

OF

Mr. ALEXANDER SIEMENS, M. Inst. C.E. President).

In taking this chair, and in thanking you sincerely for having elected me to be your President during this year, it is only natural that I should remind you of the fact that the late Sir Wm. Siemens was your first President.

For this reason I may claim to be the first representative of the second generation of electrical engineers who have been called into separate existence by the founding of this Institution 22 years ago.

During this period the Institution has grown from small beginnings to its present flourishing condition, thanks to the ability and energy of its founders and of my predecessors in this chair, who have spared neither time nor trouble to secure for electrical engineers the position to which the growing importance of the applications of electricity entitles them.

In these endeavours they have been most ably assisted by the permanent staff of our Institution; but the greatest aid has been the benevolent friendship of the parent Institution and its officers.

The permission to use this hall for their meetings started the Society of Telegraph Engineers with a standing in the engineering world that it would have cost years of work to achieve elsewhere; and the kindly counsel of the veteran Secretary of the Institution of Civil Engineers has often guided the Society in times of difficulty during the period of infancy, and we sincerely hope that he will long continue his useful work in this building.

The contrast which exists in the applications of electricity at the time of the founding of this Institution and at the present time, has been so clearly and ably put forward by Mr. Preece in his Address last year, that it would be wasting your time if I entered into any details to illustrate the progress.

On the other hand, it may not be out of place to analyse the various factors which have influenced the development of our profession from the time at which telegraphy was the only important practical application of electricity, until now, when it is called upon to supply energy for an immense variety of purposes.

During the past 22 years our profession, and with it the Society of Telegraph Engineers, have changed their character, until these and the scope of their activities have become much more comprehensive, and much more intimately connected with the everyday life of the general public.

With reference to this, telegraphy may be compared to the railways, as they both are for the indiscriminate use of the general public, and it is only an exception if a railway or a telegraph line is constructed for private purposes only.

For working both these lines a special staff is required, and general rules for their use have to be adhered to by everybody; while in the modern applications of electricity the chief aim is to distribute the electrical energy so that each individual user can apply it in the manner and during the time that it best suits his convenience.

I need not recapitulate the reasons which for a long time

made this distribution of electrical energy commercially impossible; but when these difficulties had been overcome, and the electrical engineers were ready to supply the public, it was found that, excepting the Corporation of the City of London, there existed no authority in the United Kingdom that could permit the laying of underground mains, and that a special Act of Parliament was requisite.

To the unsophisticated mind this appeared to be extremely simple, as all that was needed was to extend the powers of the various authorities to whose care the laying of water and gas pipes and of telegraph lines was entrusted, so that they could deal in a similar manner with electricity mains.

Some of the electric light companies were of opinion, however, that the same object would be attained if they received powers from Parliament to make agreements with the local authorities, subject in every case to the approval of the Board of Trade, for establishing a system for distributing electrical energy in the various districts; and in pursuance of this policy several private Bills were filed for the session of 1882.

The Government of the day did not consider it to be of public advantage that a limited number of electric light companies should have such roving powers, but brought in a general Bill with the intention of facilitating and expediting the general application of electricity.

With this object in view powers were to be given under the Bill to the Board of Trade to grant licenses or provisional orders to electric light companies.

The license to establish a system of electrical distribution in any district was to be granted to an electrical company who had succeeded in gaining the consent of the local authority; and its conditions were to be settled between the local authority and the company, subject to some general provisions to be drawn up by the Board of Trade, and subject to the sanction of the Board of Trade.

In districts where the local authority objected, the electric light company should, nevertheless, be able to establish itself by means of a provisional order of the Board of Trade; but to obtain

this the company had to prove that the majority of the inhabitants of the district desired to have facilities for obtaining electrical energy.

It will be observed that in this draft the license was intended to be the usual way of obtaining power to lay underground mains, and the formalities for settling it were extremely simple; the provisional order, on the other hand, was to be resorted to in exceptional cases as a means of overcoming the objection of local authorities.

This is confirmed by the fact that in the draft the duration of the license and of the provisional order were equal.

These benevolent intentions were, however, thoroughly upset during the passage of the Bill through Parliament, and the Electric Lighting Act (1882), which was the outcome of the discussions before a Select Committee, has given rise to angry denunciations on account of the obstacles which, in the opinion of many, it was raising to an early introduction of lighting by electricity on a large scale.

Curiously enough, nobody during the passing of the Act, or afterwards, seemed to care much about the fate of the licensing system, which was completely stripped of its importance, and alluded to by the learned counsel on both sides as suitable only for experimental purposes. Following up this train of ideas, the duration of a license was curtailed to seven years.

Had the intention of the Government, however, been carried out as at first designed, we should now enjoy in the United Kingdom the same facilities of establishing electric supply systems that have aided the development of the electrical industries so much in other countries, instead of being obliged to apply to Parliament in each separate instance, at great trouble and expense.

Disregarding entirely this vital alteration of the Bill, another provision was seized upon to explain the failure of so many electric enterprises to which the aid of the public had been invited about that time; you all know that this was the clause giving the local authority the right to buy out the electrical company after the lapse of 21 years, paying only the market value of the plant.

This agitation was continued until, seven years later, the objectionable clause was modified, and in consequence of this alteration it was said that the confidence of the public in electrical enterprises had been restored.

At the same time, the system of granting powers by way of a license was practically dropped altogether, and since then the Board of Trade has declared its intention not to grant provisional orders to electric light companies unless they have obtained the consent of the local authority, thereby abandoning entirely the original object of the provisional orders.

The ultimate result of all this legislation has, therefore, been to create a number of difficulties in the establishment of distributing systems in the United Kingdom; in fact, the formalities of applying for a provisional order are very similar to those required for a private Bill, so that practically we are not in a very much better position than before the passing of the Electric Lighting Act (1882).

In order rightly to understand the influence which this legislation exercised on the development of the electrical industry, it is necessary to examine into the character and the number of the applications made to the Board of Trade under these Acts, and to trace how many of them have led to the establishment of distributing systems.

Taking first the case of the electric light companies, or, as the Act calls them encouragingly, "the undertakers," we find that in 1883, 55 provisional orders were granted, all of which have been revoked; in 1884, 3 provisional orders and 1 license were granted, all of which have been revoked; in 1885, 1 license was granted for the lighting of St. Austell, and this has been put into operation; in 1886, 1 provisional order was granted to the Chelsea Electricity Supply Company: this also has been carried out; 4 licenses granted during the two following years, 1887 and 1888, have since been revoked; so that, up to the time of the passing of the amending Act (1888), 1 license and 1 provisional order are the sole survivors.

These facts clearly indicate that under the Electric Lighting Act (1882) the undertakers have not succeeded in their object

to make electrical energy obtainable as a household commodity. It is, of course, quite another question whether there were not very strong causes of another kind which prevented the powers obtained under the Act from being exercised.

Since the Electric Lighting Act (1888) was passed, a new impetus was given to these enterprises, and, without examining the result of each year's applications separately, the grand total of the undertakers' efforts is that since 1882 138 provisional orders have been applied for, and 15 licenses; of these, 81 provisional orders and 9 licenses have been revoked, so that 57 provisional orders and 6 licenses are still in force. To this number 2 provisional orders have to be added, which have been transferred from local authorities to undertakers.

An electric supply has been established, or the work is actually taken in hand, in 54 cases, and about 51,000 horse-power will be available. On the other hand, of local authorities, a few had obtained powers under special Acts. The City of London, as mentioned above, had been able to make some experiments of street-lighting without any special permission; but a number of them availed themselves of the opportunity given by the Electric Lighting Acts, and obtained 121 provisional orders and 6 licenses up to the end of 1892.

Of this number, 8 provisional orders and 4 licenses have been revoked, or merged in provisional orders, so that 113 provisional orders and 2 licenses granted to local authorities are still in force; but two of the provisional orders have been transferred to undertakers, as mentioned above.

Under these powers 51 electrical systems of distribution, with 33,000 horse-power, have been established or are in course of construction, while in almost all the other instances the intention soon to carry out the work is apparent.

With your permission, a table, giving the details of all these applications and of their fate, will be added to the Address, if you consider it worthy to be printed in the transactions of our Institution.

From the figures which I have given, it is, however, plainly apparent that the local authorities will very shortly have a good

many more stations at work than the electric lighting companies; and, in my opinion, this is as it should be.

The financial success which has invariably attended the municipal electric enterprises has relieved the rates at the expense of the wealthier classes in a perfectly legitimate manner; and the more electricity becomes one of the common necessaries of life, the more desirable it is that its supply should be in the hands of the community, and not in those of monopolists.

A strange fact in connection with this subject is that the great majority of the local authorities should have waited until the passing of the Electric Lighting Act (1888) before applying for powers to supply electricity, for it must not be forgotten that their position was in no way affected by the alteration of the Electric Lighting Act (1882). The explanation must perhaps be looked for in the exaggerated expectations that were raised by the statements of company promoters in the year 1882, when the most reckless assertions were made as to the results to be obtained by establishing electric systems of distribution.

The natural consequence was that the inquiries set on foot by various local authorities in no way confirmed the sanguine estimates that had been dangled before the public to obtain its support; and the total failure of the electric light companies to carry out a single one of the orders and licenses obtained by them in the years 1883 and 1884, made the local authorities hesitate before they embarked the ratepayers' money in such precarious undertakings.

Fortunately for the progress of our industry, there were some Corporations who could be convinced by the result of their inquiries that the use of electric light would be very advantageous for a variety of purposes, and that the knowledge and ability of the electrical engineers had progressed sufficiently to make a profitable distribution of electricity from a generating centre possible.

We have seen that their example has been largely followed, and there is every prospect of a continuous and ever-increasing development of this branch of electrical engineering.

To be sure, in foreign countries, especially in the United

States, the use of electricity is much more common than here; but this is the natural outcome of the greater facilities for establishing centres of supply under the laws of the various countries, where the local authorities in the majority of cases have the power to make agreements with electrical companies for supplying the district with electrical energy for various purposes.

Another important factor in retarding the spread of the applications of electricity in this country is the otherwise very laudable desire of the electrical engineers to show in every new undertaking a distinct advance on its predecessors.

In this way the details of construction are undergoing a constant change—in strong contrast to the United States, where the leading manufacturers have their standard sizes of plant and accessories; these are manufactured wholesale by specially designed machinery, and can therefore be supplied much more cheaply than apparatus specially constructed for each case.

At the same time the whole transaction is greatly simplified by the absence of long negotiations about the construction of the apparatus, the town which is to be lighted simply specifying how many glow lights and arc lights are to be supplied.

This system of working has certainly been instrumental in accelerating the introduction of electricity for a variety of uses throughout the States; but it can hardly be pretended that such a cast-iron application of the same apparatus under a variety of circumstances can lead to the most economic results, nor has it been possible to keep up the quality of the work to the English standard.

Those of you who visited the World's Fair at Chicago last year, and examined a little into the details of workmanship and design, will doubtless agree that Sir Richard Webster was fully justified, in his address to the Society of Arts, in contrasting the American and the English exhibits in this respect, very much in favour of the latter.

However much other causes may have contributed to delay the development of electrical engineering, it is clear that the principal one must be looked for in the exaggerated expectations that were raised, either by ignorance or by design, when the

general public first seriously thought of regarding electricity as a commodity for everyday use.

At that time the promoters of electric companies preached to the public that electricity was in its infancy, that the laws of this new science were totally unknown, and that wonders could be confidently expected from it. There was a short time of excitement to the public and of profit to the promoters; then the confidence of the public in electricity was almost destroyed, and could only be regained by years of patient work.

That the electrical industry was not altogether killed by all these adverse factors is undoubtedly due to the firm scientific basis on which it rests, and to the advantages which the applications of electricity possess as compared with other means for accomplishing the same ends.

In a discourse before the Royal Institution I had an opportunity of reminding the audience that during the last 60 years the most eminent scientific men have studied the phenomena produced by electricity, and that, in consequence, the laws which govern electric currents were perfectly well known when the supply of electricity on a large scale became commercially possible.

Since that time the study of electrical phenomena has been carried on with even greater zeal than before, and electrical engineering is now in no danger of lagging behind for want of theories, but is largely aided in its progress by the painstaking investigations carried on in many laboratories, both in England and abroad.

While electrical engineering is thus closely allied to physical science, it has quite as intimate a relation to mechanical engineering; in fact, its real progress dates from the time when the close connection of electrical and mechanical engineering was thoroughly recognised; and since then these two branches of engineering have reacted on one another to their mutual advantage.

The contrast between present practice and that of the pioneers of our profession is at once recognised in reading the first papers and reports on dynamo-electric machines, where particular stress is laid on the small size and on the low weight of a dynamo to

produce a given result; but the necessity of having the moving parts durable, and of not always working the machine up to its maximum power, was completely ignored in the desire to produce a large effect with the minimum expenditure of materials.

A glance at a modern dynamo, especially when it is built on the same lines as a machine of 20 years ago, will at once reveal the progress of mechanical design that has taken place in the interval.

The circumstance that at first only weak currents of electricity were utilised for practical purposes, and that during this period the electrical appliances were constructed like scientific instruments, had undoubtedly brought about this neglect of mechanical considerations, and a healthy reaction could only take place after the mechanical engineer had taken the management of the applications of electrical energy from the hands of the instrument maker.

On the other hand, the requirements for driving dynamos to the best possible advantage have served as no mean incentive for mechanical engineers to introduce a number of important improvements into the design of steam engines; in fact, the class of high-speed economical engines may be said to have been called into existence by them, and this has led to the use of direct-driven dynamos, in which this country undoubtedly has taken the lead.

In another direction the governing of the speed of the steam engines has been vastly improved, although at first the mechanical engineers regarded the complaints of the electrical engineers simply as an excuse to shift the blame for the bad performance of their dynamos on to the steam engine.

They very soon learned, however, the importance of running at an unvarying speed, and the result is that even comparatively cheap steam engines can be obtained nowadays that govern infinitely better than a high-class engine of 20 years ago.

Originally the steam dynamos were designed for use on board ship, where economy of space is of importance, and great credit is due to the Admiralty for introducing very early a system of testing which has been no small incentive to all concerned to improve the dynamos as well as the steam engines.

In these tests the dynamo is run for a number of hours at its maximum output, and no part of it must get hotter than the surrounding air by more than a prescribed number of degrees of heat.

Nothing could be simpler than this test, and at the same time it is the most reliable way of finding out whether a dynamo has been constructed suitably for its work.

During the same run the water is measured which, in the form of steam, is supplied to the engine, and the relation between the water consumed and the electrical energy supplied to the electrical circuits determines the merit of the steam dynamo tested.

By far the most important connection between mechanical and electrical engineering is, however, the transmission of power, which has of late acquired so much prominence.

If the first stage of the development of the electrical industry was closely connected with telegraphy, the second step may be said to have been taken when electric lighting was introduced, and now it seems that transmission of power is the problem which electrical engineers have to grapple with in the near future.

The success of electric tram lines has undoubtedly contributed to direct general attention to the transmission of power by means of electricity, but great care will have to be exercised so as not to start in a direction that can lead to no practical results.

Many schemes have been started to introduce electricity as the motive power on the main lines of railway, and to accelerate at the same time the speed of the trains very considerably, even up to 200 miles per hour.

It would be rash to say that such a speed will not be attained some day, but in my opinion none of these schemes can be carried out on a commercial basis with the means at present at our disposal.

Trebling the speed of the trains necessitates a radical alteration in the laying of the permanent way, a thorough reconstruction of the carriages, and demands an amount of power that we have no means at present of estimating accurately, nor have we motors that could produce it with a moderate weight.

Even if these obstacles are overcome, the enormous capital outlay could only be justified if a very frequent service was kept up, as in the case of successful electric tramways. In most schemes it is, in fact, proposed to run single carriages at short intervals between important towns; but up till the present time it has not been possible to convince capitalists that such a service would pay, either between Vienna and Buda-Pesth, or between Chicago and St. Louis, which are the most notable instances of such schemes.

Leaving these ambitious projects out of consideration, enough scope remains for the development of electric traction in this country to render a healthy activity in this branch of our industry probable for a number of years; and the report of the Hybrid Committee which sat last year has removed, let us hope, a very serious obstacle to electric traction.

As the rules which the Board of Trade has drawn up in accordance with the instructions of this committee are still under consideration, it would obviously not be in order to criticise the version that has been published; it would, however, be hampering the industry if too many details were too accurately prescribed.

In this connection it must not be forgotten that in the past the industries of this country have been developed, to the great advantage of the nation, with very little legislative interference; and it would at present be premature to make the conditions regulating electric traction too stringent, as the working out of this branch of electrical engineering is by no means completed.

Besides traction, there is the distribution of power, in which mechanical engineering is of the greatest influence on the successful application of electricity.

It is, of course, a purely electrical problem to deliver your current either at a standard voltage, or in a constant quantity, at all points of your network of mains; but the application of the motors to the work they are required to do, and the determination of their dimensions, involve principally mechanical considerations.

How much there is still to be done in this respect was made

apparent during the discussion of Professor Forbes's paper on the proposed utilisation of water power at the Niagara Falls. Although the prevailing opinion seemed to be that for transmission to a great distance alternate currents only can be utilised, I believe that of the actually established long-distance transmissions the greater part are worked with continuous currents.

No hard-and-fast rule can apparently be laid down that either the continuous or the alternate current should be preferred in all cases where power has to be transmitted to a distance; and in judging of the merits of the two systems the proper conclusion can only be arrived at if the commercial aspect of the case is allowed to decide the question.

The installation of rotary-current motors at the Frankfort Exhibition, driven by the water power at Lauffen, was undoubtedly an engineering success, and served very well for the purposes of an exhibition; but nobody has attempted to do everyday work on the same lines, for the simple reason that it would have been much cheaper to produce the power in Frankfort by steam engines than pay the commercial interest on the outlay that had been necessary to establish the transmission from Lauffen.

The generating plant of this installation is now used for the lighting of Heilbronn, and there are a few other instances where rotary currents are used for long-distance transmissions; but, as I said just now, it would be wrong to generalise by preferring either the one or the other method of transmission in all cases.

Another great field for electric motors is just being opened by their introduction for distributing power in works, with a view of abolishing shafting, leather belts, and other intermediate gearing, and of giving each lathe or other tool an independence that cannot be attained under the present system.

A most interesting paper on this subject was read by M. Castermans before the Society of Engineers in Liége in August, 1892, in which he compares in detail several proposals for distributing power in a new small arms factory, that has since been erected at Herstals.

The result he arrived at was that with electrical motors he could exert on the working machines 70 per cent. of the power generated by the main engine, while the next best other method gave only 63 per cent., when the shops were working at their full capacity.

In these problems, again, mechanical engineering questions decide whether the application of electricity is justifiable; and it is quite apparent that an electrical engineer requires to be well versed in a variety of subjects if he wishes to keep in the front rank.

Fortunately for our profession, the question of technical education generally has received particular attention during the last quarter of a century; and omitting all reference to other occasions when this subject has been brought before this Institution, I will only remind you of the eloquent Address of Professor Ayrton, which no doubt is still fresh in your memory.

It will, therefore, not be necessary for me to repeat his lucid exposition of the transition from the former system of pupilage to the modern one of educating the budding engineers in colleges and their laboratories, which has supplemented, and to a great extent supplanted, the old one.

No doubt this altered system of education is capable of producing a class of men who are well adapted to explore the untrodden fields of applied electrical energy, where the problems constantly demand a thorough knowledge of scientific principles; but, in combination with this, an equally extensive acquaintance with practical possibilities is requisite.

This most important co-operation of science and practice is essential for all real success, and no doubt it appears to be superfluous to insist on the necessity of bearing this in mind; but a perusal of patent specifications will at once convince you that either the one or the other factor is sadly wanting in many would-be inventors.

Years ago it was science that was most conspicuous by its absence in these documents; but in the present time it is very often obvious that the inventor has no clear conception how his invention could be carried out so as to make it useful to mankind,

and even fails to see the obvious impossibility of realising his ideas in the way he claims in the specification.

As usual, it is very difficult to steer the middle course; and if the scientific man had for years to cry in the wilderness because his pursuits did not receive the proper attention in the education of engineers, it seems now to be the turn of the practical man to warn students that there is something more to be learned besides scientific truths before they can aspire to be recognised as engineers.

It has always appeared to me that at school the mental powers should be principally exercised in a way to make them fit for learning, and that at the same time they should become accustomed to the careful consideration of a problem in its various aspects. Although it has been the fashion of late to deprecate the study of Latin and Greek, I am quite certain that the attack is made from quarters where the mental training which the study of these languages entails is not appreciated at its right value, nor is the enormous advantage considered which their knowledge gives in the study of modern languages.

After the mental powers have been prepared in this way, it is of no great consequence whether most of the details of the school teaching are speedily forgotten or not; the essential point is that the student should have acquired a good method of learning, so as to assimilate to the best advantage the course of training he attends at college.

While the teaching at school has a general character, and embraces chiefly subjects that ought to be known to all classes, at college the various professions are differentiated, and in each branch the students learn the general principles that ought to govern them in their future career.

Formerly it was possible to let the course of scientific studies embrace all that was known in any particular branch; in fact, the general principles and the interdependence of the various branches were not, and to some extent are not yet, properly understood.

To attempt a similar course at the present time is simply impossible, and the danger that has to be avoided in our scientific colleges is the tendency to teach our profession too much in detail.

Besides overwhelming the professors with work, such a course

is apt to create in the students the conviction that on leaving college with a first-class certificate they know all that can possibly be known, and that anything that does not fit in with the theory of their pet professor must necessarily be condemned.

A fault into which young men are liable to fall, when they come full of honours from college, is that they consider the passing through workshops beneath their dignity, especially when they have attended for the prescribed time in the workshop of the college. They quite forget that the practical conditions that prevail in works where machinery is made for sale differ entirely from those of a laboratory, where the only aim is to give the students an opportunity of acquiring manual skill.

Another class of students commences practical work with the greatest interest, and the fixed determination to introduce with all possible speed the various improvements which the difference of the practical work with which they come in contact from the teaching at college suggests to them.

On all these students it cannot be impressed too much that the practical training is of quite as much importance as the scientific course at college; in fact, in most cases the conclusions of pure science have to be modified by practical considerations before a useful application of science can be produced.

For this reason it is highly desirable that the teaching at engineering colleges should be confined to general principles, as far as the applications of science are concerned, but that the students should become thoroughly well acquainted with the mental tools that are used in scientific investigations, such as mathematics, the general principles of chemistry, and of the branches of natural philosophy.

While the student is trained afterwards in practical work, he has time to select what special branch of the profession he wishes to devote his life to, and no doubt he will find that his college studies have to be supplemented by reading up the various technical works referring more particularly to the selected branch.

If he has been able to acquire a certain knowledge of modern languages, he will find his labours lightened very materially by having a much larger range of literature to select from.

In this respect electrical engineering has been especially fortunate, for it has more than any other profession an international character, and this Institution has from the very commencement counted among its members distinguished electrical engineers of many nationalities.

It is quite true that after a time the principal foreign nations formed their own Electrical Institutions, but the international character of the profession has been kept up by the congresses which have met from time to time with a view of regulating electrical matters of international importance.

At the official congress which met last year at Chicago, an international system of units of measurement has been settled, or, rather, readjusted, for the electrical engineers have from the beginning enjoyed the immense advantage that their units of measurement have been the same in all countries.

Not only has this circumstance greatly promoted the intercommunication between the various nations, but the character of the electrical units facilitates the demonstration of the interdependence of the various forms of energy, and simplifies the calculations of the engineering profession.

If a proof were necessary of the utility of having the same units understood in all civilised countries, it is only necessary to observe the conditions and the tendencies that prevail in other matters of international interest.

It is chiefly owing to telegraphy that the conditions of modern life differ so essentially from the state of things before the means of quickly communicating with distant parts were at the service of the community at large.

Through the ever-increasing network of telegraph wires all mankind is drawn together, and the mutual reaction of the affairs of distant nations is very well illustrated by the newspapers of all countries vieing with each other to bring the latest news from all parts of our globe, and by the effect this news produces at home.

Not only are industrial enterprises greatly aided by the possibility of watching their progress in distant countries as easily as it was formerly possible to follow the fortunes of works in the

next county, but the distribution of the commodities of life can be regulated in such a way that an extraordinary demand in one country can be met by an extraordinary supply from another one.

Under such conditions of inter-communication, it is not to be wondered at that attempts have been made—and, in fact, have been to a great extent successful—for facilitating the intercourse between nations in various directions where an international agreement could do away with existing difficulties.

One of the most important international conventions is the Postal Union, into which most nations of our globe have entered, and whose influence is brought home to us every day.

In another direction an effort has lately been made to make the mode of reckoning time more uniform, and the result is that Greenwich time has practically been adopted in a great many civilised countries, by making the local time either the same, or differing from Greenwich by one hour or by multiples of an hour.

An even more important agreement among many nations has existed now for more than a quarter of a century by their adopting the metrical system of measurement; and it is well worth while seriously to consider the effect of this concerted action on the part of foreign nations, as it forms an ever-increasing obstacle for the successful competition of English manufacturers.

An ideal system of measurement should be based on units which can be reproduced at any time and at any place with mathematical precision, and you all know that the metrical system was intended to embody this desirable condition.

From various causes, into which I need not enter here, the attempt has failed; even the kilogramme does not bear the relationship to the linear units which it originally was intended to have, so that the bases of the metrical system are now an arbitrary metre and an arbitrary kilogramme.

All the same, its very general adoption has proved a very great convenience, and there is little doubt that the introduction of international electrical units has been accomplished with such facility because they are based on the metrical system.

When we recollect that it was a German professor who suggested the absolute system of measurement, that the British

Association first established practical electrical units, that the metrical system is of French origin, and that the electrical system of measurement was elaborated by discussions between engineers and scientific men of all nations at the various congresses, we cannot wonder that a very perfect system has been the outcome, and that its general adoption in all countries has followed without discussions, although the formal recognition may not yet have been pronounced in all cases.

Even in this system it has been found necessary to settle one of the units—the ohm—in an arbitrary manner, as it was recognised that for practical purposes it was better to have an arbitrary but fixed standard, than to correct the unit every time that an improvement in methods, or in instruments, admitted of determining it with greater accuracy than before.

It is well worth while to reflect on the lesson which this fact conveys, viz.—that, in spite of the earnest endeavours and the painstaking collaboration of most competent men, it has not been possible to follow out in practice the dictates of pure science, but that a compromise was found to be inevitable.

The conclusions to which this consideration of the influences that have shaped the course of electrical engineering leads us, may well awake in us the hope of an ever-increasing activity and of an ever-growing importance of the applications of electricity; but we must not forget that we can only succeed if we understand how to adapt our work to practical requirements without losing sight of scientific laws.

For this reason nothing can further the interests of our profession more than a free and frequent interchange of ideas between the engineers, who carry out the practical applications, and the scientific men, who investigate the nature of electricity.

In the past this Institution has been the arena in which many subjects have thus been discussed to the advantage of everybody concerned; and it is the duty of all its members to contribute, either by reading papers or by criticising those submitted by others, to the development and to the ever-increasing importance of electrical engineers.

PROVISIONAL ORDERS AND LICENSES,

UNDER ELECTRIC LIGHTING ACTS, 1882 AND 1888.

1883.

1. LOCAL AUTHORITIES.

(a) *Provisional Orders.*

District.	To whom Granted.	Present State.	Engines I.H.P.	Output, K.W.
Barton, Eccles, &c....	The Local Board	Repealed ...	—	—
Birkdale	,, ...	Revoked ...	—	—
Bradford	The Corporation	Working ...	1,610	970
Brighton	,, ...	,, ...	1,300	870
Bristol	,, ...	,, ...	1,750	806
Carlisle	,, ...	Revoked ...	—	—
Grantham	,, ...	,, ...	—	—
Greenock	The Board of Police	Waiting ...	—	—
Nelson	The Local Board	Working ...	210	140
Norwich	The Corporation	Revoked ...	—	—
Richmond	The Vestry	Constructing	—	—
St. Pancras	,, ...	Working ...	1,450	780
Scarborough ...	The Corporation	Merged ...	—	—
Ulverston	The Local Board	Revoked ...	—	—

(b) *Licenses.*

None.

2. COMPANIES.

(a) *Provisional Orders.*

District.	To whom Granted.	Present State.	Engines I.H.P.	Output, K.W.
Aston	South Staffordshire E. L. Co.	Revoked ...	—	—
Balsall Heath ...	,, ,,	,, ...	—	—
Barnes and Mortlake	Metropolitan (Brush) E. L. Co.	,, ...	—	—
Bermondsey	,, ,,	,, ...	—	—
Birmingham	Incandescent E. L. Co. ...	,, ...	—	—
Cambridge	Provincial (Brush) E. L. Co.	,, ...	—	—
Canterbury	South Eastern(Brush) E.L.Co.	,, ...	—	—
Chelsea	Metropolitan (Brush) E. L. Co.	,, ...	—	—
Chiswick	,, ,,	,, ...	—	—
Clerkenwell	,, ,,	,, ...	—	—
Croydon	South Eastern (Brush) E.L.Co.	,, ...	—	—

PROVISIONAL ORDERS AND LICENSES—*continued.*

District.	To whom Granted.	Present State.	Engines I.H.P.	Output, K.W.
Dudley	South Staffordshire E. L. Co.	Revoked ...	—	—
Dundee	Brush E. L. Co. of Scotland	,, ...	—	—
Finchley	Metropolitan (Brush) E. L. Co.	,, ...	—	—
Folkestone	South Eastern (Brush) E. L. Co.	,, ...	—	—
Gravesend	,, ,,	,, ...	—	—
Greenwich	Metropolitan (Brush) E. L. Co.	,, ...	—	—
Hackney	,, ,,	,, ...	—	—
Hampstead	Ferranti-Hammond E. L. Co.	,, ...	—	—
Hanover Square ...	Swan United E. L. Co. ...	,, ...	—	—
High Wycombe ...	Provincial (Brush) E. L. Co.	,, ...	—	—
Holborn	Metropolitan (Brush) E. L. Co.	,, ...	—	—
Hornsey	,, ,,	,, ...	—	—
Ipswich	Provincial (Brush) E. L. Co.	,, ...	—	—
Islington	Metropolitan (Brush) E. L. Co.	,, ...	—	—
Limehouse	,, ,,	,, ...	—	—
Lowestoft	Provincial (Brush) E. L. Co.	,, ...	—	—
Luton	,, ,,	,, ...	—	—
Maidstone	South Eastern (Brush) E. L. Co.	,, ...	—	—
Margate	,, ,,	,, ...	—	—
Poplar	Metropolitan (Brush) E. L. Co.	,, ...	—	—
Redditch	Incandescent E. L. Co. ...	,, ...	—	—
Rochester	South Eastern (Brush) E. L. Co.	,, ..	—	—
Rotherhithe	Metropolitan (Brush) E. L. Co.	,, ...	—	—
St. George, Southwark	,, ,,	,, ...	—	—
St. George's-in-the-East	,, ,,	,, ...	—	—
St. Giles	,, ,,	,, ...	—	—
,, ...	Pilsen-Joel & General E. L. Co.	,, ...	—	—
St. James & St. Martin	Edison E. L. Co.	,, ...	—	—
St. Luke	Metropolitan (Brush) E. L. Co.	,, ...	—	—
St. Olave	,, ,,	,, ...	—	—
St. Saviour's, Southwark	,, ,,	,, ...	—	—
Saltley	South Staffordshire E. L. Co.	,, ...	—	—
Shoreditch	Metropolitan (Brush) E. L. Co.	,, ...	—	—
South Kensington ...	Swan United E. L. Co. ...	,, ...	—	—
Strand	,, ,, ...	,, ...	—	—
Sudbury	Provincial (Brush) E. L. Co.	,, ...	—	—
Sunderland	North Eastern E. L. Co. ...	,, ...	—	—

PROVISIONAL ORDERS AND LICENSES—*continued.*

District.	To whom Granted.	Present State.	Engines I.H.P.	Output, K.W.
Victoria	Swan United E. L. Co. ...	Revoked ...	—	—
Walsall	Incandescent E L. Co. ...	,, ...	—	—
Wandsworth... ...	Metropolitan (Brush) E.L. Co.	,, ...	—	—
Wednesbury... ...	South Staffordshire E. L. Co.	,, ...	—	—
West Bromwich ...	,, ,, ,,	,, ...	—	—
Whitechapel ...	Metropolitan (Brush) E.L. Co.	,, ...	—	—
Wolverhampton ...	South Staffordshire E. L. Co.	,, ...	—	—

(*b*) *Licenses.*

None.

1884.

1. LOCAL AUTHORITIES.

(*a*) *Provisional Orders.*

Bury St. Edmunds...	The Corporation	Revoked ...	—	—

(*b*) *Licenses.*

None.

2. COMPANIES.

(*a*) *Provisional Orders.*

Edison & Swan United	Edison & Swan United E.L. Co.	Revoked ...	—	—
Fulham	West Middlesex E. L. Co. ...	,, ...	—	—
St. James, St. Martin, and St. George ...	West London E. L. Co. ...	,, ...	—	—

(*b*) *Licenses.*

Colchester	South Eastern (Brush) E. L. Co.	Expired ...	—	—

1885.

1. LOCAL AUTHORITIES.

(*a*) *Provisional Orders.*

None.

(*b*) *Licenses.*

Dalton-in-Furness ...	The Local Board	Expired ...	—	—

PROVISIONAL ORDERS AND LICENSES—*continued.*

2. COMPANIES.

(*a*) *Provisional Orders.*

None.

(*b*) *Licenses.*

District.	To whom Granted.	Present State.	Engines I.H.P.	Output, K.W.
St. Austell	John Edward Veale	Working ...	140	83

1886.

1. LOCAL AUTHORITIES.

(*a*) *Provisional Orders.*

None.

(*b*) *Licenses.*

Dundalk	The Town Commissioners ...	Waiting ...	—	—

2. COMPANIES.

(*a*) *Provisional Orders.*

Chelsea	Chelsea Electricity Supply Co.	Working ...	2,000	1,280

(*b*) *Licenses.*

None.

1887.

1. LOCAL AUTHORITIES.

Neither Provisional Orders nor Licenses.

2. COMPANIES.

(*a*) *Provisional Orders.*

None.

(*b*) *Licenses.*

Kensington Court ...	Kensington Court E. L. Co....	Merged ...	—	—

1888.

1. LOCAL AUTHORITIES.

Neither Provisional Orders nor Licenses.

PROVISIONAL ORDERS AND LICENSES—*continued.*

2. COMPANIES.

(*a*) *Provisional Orders.*

None.

(*b*) *Licenses.*

District.	To whom Granted.	Present State.	Engines I.H.P.	Output, K.W.
Kensington Court ...	Kensington Court E. L. Co.	Merged ...	—	—
Liverpool	Liverpool Electric Supply Co.	„ ...	—	—
St. James	St. James & Pall Mall E. L. Co.	„ ...	—	—

1889.

1. LOCAL AUTHORITIES.

(*a*) *Provisional Orders.*

Swansea	The Corporation	Waiting ...	—	—

(*b*) *Licenses.*

Dublin	The Corporation	Merged ...	—	—
Wimbledon	The Local Board	Waiting ...	—	—

2. COMPANIES.

(*a*) *Provisional Orders.*

Birmingham ...	Messrs. Chamberlain & Hookham	Merged ...	—	—
House-to-House ...	House-to-House E. L. Co. ...	Working ...	1.020	550
Kensington	Kensington and Knightsbridge E. L. Co.	„ ...	2,120	1,306
Liverpool	Liverpool Electric Supply Co.	Merged ...	—	—
London Electric Supply Corporation	London Electric Supply Corporation	Working ...	5,000	4,200
Mid London ...	Metropolitan El. Supply Co.	„	7,400	4,800
West London ...	„ „	„		
Notting Hill ...	Notting Hill E. L. Co. ...	„ ...	560	480
St. Martin	Electricity Supply Corporation	„ ...	1,700	1,000
South Kensington ...	Chelsea Electricity Supply Co.	Merged ...	—	—
Westminster... ...	Westminster Electric Supply Corporation...	Working ...	4,700	2,520

(*b*) *Licenses.*

Kensington	Kensington Court E. L. Co.	Merged ...	—	—

PROVISIONAL ORDERS AND LICENSES—*continued.*

1890.

1. LOCAL AUTHORITIES.

(a) *Provisional Orders.*

District.	To whom Granted.	Present State.	Engines I.H.P.	Output, K.W.
Aberdeen	The Corporation	Constructing	320	—
Accrington	,, ...	Sanctioned	—	—
Ayr Burgh	,, ...	Waiting ...	—	—
Bacup	,, ...	,, ...	—	—
Barnsley	,, ...	,, ...	—	—
Bedford	,, ...	,, ...	—	—
Belfast	,, ...	Constructing	500	—
Birkenhead	,, ...	Waiting ...	—	—
Blackburn	,, ...	Constructing	550	—
Blackpool	,, ...	Working ...	580	200
Burnley	,, ...	,, ...	360	184
Burton-on-Trent ...	,, ...	Constructing	200	—
Bury (Lancs.) ...	,, ...	Sanctioned	400	—
*Cambridge	,, ...	Working ...	600	450
Cheltenham	,, ...	Sanctioned	—	—
Chester	,, ...	,,	—	—
Darlington	,, ...	Waiting ..	—	—
Derby	,, ...	Working ...	850	—
*Dover	,, ...	Waiting ...	—	—
Dundee	Gas Commissioners	Working ...	730	436
Fleetwood	Improvement Commissioners	Constructing	150	—
Glasgow	The Corporation	Working ...	1,860	1,230
Great Yarmouth ...	,, ...	Sanctioned	—	—
Hastings	,, ...	Waiting ...	—	—
*Hove	The Hove Commissioners ...	Working ...	170	132
Huddersfield ...	The Corporation	,, ...	1,000	500
Hull	,, ...	,, ...	600	320
Lancaster	,, ...	Constructing	400	—
Leicester	,, ...	,,	850	—
Malvern	The Local Board	Waiting ...	—	—
Manchester	The Corporation	Working ...	1,980	1,420
Nottingham	,, ...	Constructing	642	—
Oldham	,, ...	,,	320	—
Portsmouth	,, ...	,,	640	—
Salford	,, ...	,,	675	—

* Transferred to company.

PROVISIONAL ORDERS AND LICENSES—*continued.*

District.	To whom Granted.	Present State.	Engines I.H.P.	Output, K.W.
Stafford	The Corporation	Sanctioned	480	—
Stockton-on-Tees ...	"	Waiting ...	—	—
Tiverton	"	" ...	—	—
Walsall	"	Sanctioned	400	—
Wigan	"	Waiting ...	—	—
Wolverhampton ...	"	Constructing	625	—
Worcester	"	"	800	—
York	"	Sanctioned	—	—

(*b*) *Licenses.*

Dublin	The Corporation	Merged ...	—	—

2. COMPANIES.

(*a*) *Provisional Orders.*

Ashton-under-Lyne	Municipal E. L. & Power Corp.	Revoked ...	—	—
Bognor	The Electric Trust, Limited...	" ...	—	—
Bournemouth ...	Brush El. Engineering Co....	Working ...	650	375
" ...	South of England House-to-House El. Co.	Revoked ...	—	—
Chatham, &c. ...	Chatham, Rochester, & District E. L. Co.	Working ...	—	258
Coatbridge	Scottish House-to-House Electricity Co.	Constructing	—	—
Eastbourne	Eastbourne E. L. Co.... ...	Working ...	360	—
Galway	Galway Electric Co.	" ...	100	50
Hastings and St. Leonards	Hastings and St. Leonards E. L. Co.	" ...	420	250
Kelvinside	Kelvinside Electricity Co. ...	" ...	—	—
City of London (Brush)	Brush El. Engineering Co. ...	"	6,170	3,130
" (East)	Laing, Wharton, & Down Construction Syndicate ...	"		
Crystal Palace ...	Electric Installation and Maintenance	" ...	750	450
Lambeth	House-to-House E.L. Supply Co.	Revoked ...	—	—
London El. Supply...	London Electric Supply Corporation	Working ..	See *ante*	—
Paddington	Metropolitan Electric Supply Corporation	" ...	See *ante*	—
North London ...	House-to-House E.L. Supply Co.	Revoked ...	—	—
St. James	St. James & Pall Mall E.L. Co.	Working ...	3,680	2,120

PROVISIONAL ORDERS AND LICENSES—*continued.*

District.	To whom Granted.	Present State.	Engines I.H.P.	Output, K.W.
Wandsworth ...	House-to-House E.L. Supply Co.	Revoked ...	—	—
Morecambe	Messrs. Andrews & Preece ...	Working ...	260	120
Moss Side & Stretford	Manchester House-to-House El. Co.	Revoked ...	—	—
Northampton ...	Northampton E.L. & Power Co.	Working ...	350	200
Oxford	Electric Installation & Maintenance Co.	Merged ...	—	—
Plymouth	Devon and Cornwall Electric Supply Co.	Revoked ...	—	—
Preston	National Electric Supply Co.	Merged ...	—	—
Preston and Fulwood	Lancashire & Cheshire House-to-House Co.	Revoked ...	—	—
Sevenoaks	The Electric Trust, Limited...	„ ...	—	—
Tunstall	„ „	„ ...	—	—
Windsor	Windsor and Eton E. L. Co....	Constructing	—	—
Woking	Woking Electric Supply Co.	Working ...	250	180
Wrexham	Wrexham & District Electric Supply Co.	Waiting ...	—	—

(*b*) *Licenses.*

Bath	H. G. Massingham	Working ...	740	300
Chelmsford	Crompton & Co.	„ ...	400	—
Newcastle & District	Newcastle & District E. L. Co.	Merged ...	—	—
Newcastle-upon-Tyne	Newcastle-upon-Tyne Electric Supply Co.	„ ...	—	—
Northampton ...	N'thampton E. L. & Power Co.	„ ...	—	—
Southampton ...	Southampton E.L. & Power Co.	Working ..	280	150

1891.

1. LOCAL AUTHORITIES.

(*a*) *Provisional Orders.*

*Acton	The Local Board	Waiting ...	—	—
Bolton	The Corporation	Constructing	540	—
Bromley	The Local Board	Waiting ...	—	—
Canterbury	The Corporation	„ ...	—	—
Cardiff	„	Constructing	800	—
*Chiswick	The Local Board	Waiting ...	—	—
Coventry	The Corporation	Constructing	600	—
Croydon	„	Waiting ...	—	—

* Transferred to company.

PROVISIONAL ORDERS AND LICENSES—*continued.*

District.	To whom Granted.	Present State.	Engines I.H.P.	Output, K.W.
Dewsbury	The Corporation	Constructing	500	—
Ealing	The Local Board	"	420	—
Edinburgh	The Corporation	Sanctioned	1,500	—
Hanley	"	Constructing	670	—
Harrogate	"	Sanctioned	—	—
Heckmondwike ...	The Local Board	Waiting ...	—	—
Hertford	The Corporation	" ...	—	—
Kidderminster ...	"	" ...	—	—
Kingston	"	Working ...	300	195
Llanelly	The Local Board	Waiting ...	—	—
Londonderry ...	The Corporation	Constructing	450	—
Newport	"	Sanctioned	635	—
Paisley	"	Waiting ...	—	—
Scarborough ..	"	Working ...	400	300
Southend	The Local Board	Waiting ...	—	—
Southport	The Corporation	Constructing	250	—
South Shields ...	"	Waiting ...	—	—
Stockport	"	" ...	—	—
Sunderland	"	Constructing	320	—
Surbiton	The Local Board	Waiting ...	—	—
Torquay	"	" ...	—	—
Tunbridge Wells ...	The Corporation	Sanctioned	—	—
Tynemouth	"	Waiting ...	—	—
Weston-super-Mare	The Improvements Commissrs.	" ...	—	—
Whitby	The Local Board	" ...	—	—
Whitehaven... ...	The Town & Harbour Trustees	Working ...	240	144

(*b*) *Licenses.*

None.

2. COMPANIES.

(*a*) *Provisional Orders.*

Birmingham ...	Birmingham El. Supply Co.	Working ...	1,050	630
Bishop's Stortford ...	Bishop's Stortford E. L. and Steam Laundry Co. ...	Revoked ...	—	—
Exeter	Exeter Electric Light Co. ..	Working ...	420	200
Ipswich	Ipswich El. Supply Co. ...	Revoked ...	—	—
"	Laurence Scott & Co. ...	" ...	—	—
Killarney	C. E. Leahy	Working ...	—	—

PROVISIONAL ORDERS AND LICENSES—*continued.*

District.	To whom Granted.	Present State.	Engines I.H.P.	Output, K.W.
Leeds	YorkshireHouse-to-HouseEl.Co	Working ...	700	350
Liverpool	Liverpool El. Supply Co. ...	" ...	3,800	2,000
Camberwell	Camberwell&IslingtonE.L.Co.	Revoked ...	—	—
City of London ...	BrushElectricalEngineeringCo.	Merged ...	—	—
Clerkenwell	" "	" ...	—	—
Islington	Camberwell &IslingtonE.L.Co	Revoked ...	—	—
St. Luke, Chelsea ...	New Cadogan & Belgrave El. Supply Co.	" ...	—	—
St. Luke, Middlesex	BrushElectricalEngineeringCo.	Merged ...	—	—
Southwark	" "	Waiting ...	—	—
Wandsworth ...	Stamford Hill, &c., E. L. and Power Co.	Revoked ...	—	—
Westminster ...	Westminster El. Supply Corp.	Working ...	See *ante*	—
Woolwich	Woolwich District E. L. Co.	" ...	40	37
Newcastle-upon-Tyne	Newcastle & District E. L. Co.	" ...	1,000	—
Norwich	Norwich Electricity Co. ...	" ..	300	180
Poole	BrushElectricalEngineeringCo	Waiting ...	—	—
Preston	National Electric Supply Co.	Working ...	710	470
Toxteth Park ...	Liverpool Electric Supply Co.	" ..	See *ante*	—
Weybridge	Weybridge Electric Supply Co	" ...	150	—
Withington	Manchester House-to-House Electric Co.	Revoked ...	—	

(*b*) *Licenses.*

None.

1892.

1. LOCAL AUTHORITIES.

(*a*) *Provisional Orders.*

*Aberystwith... ...	The Corporation	Waiting ...	—	—
Ashton-under-Lyne	"	" ...	—	—
Dublin	"	Working ...	1,000	500
Govan	The Commissioners of Police	Waiting ...	—	—
Halifax	The Corporation	Constructing	500	—
Harwich	"	Waiting ...	—	—
Kilkenny	"	" ...	—	—
Limerick	"	" ...	—	—
Hampstead	The Vestry	Constructing	800	—
Lambeth	"	Waiting ...	—	—
Shoreditch	"	" ...	—	—

* Transferred to company.

PROVISIONAL ORDERS AND LICENSES—*continued.*

District.	To whom Granted.	Present State.	Engines I.H.P.	Output, K.W.
Whitechapel ...	The Board of Works	Waiting ...	—	—
Maidstone	The Corporation	„ ...	—	—
Newbury	„	„ ...	—	—
Sutton	The Local Board	„ ...	—	—
Waterford	The Corporation	„ ...	—	—
West Ham	„	„ ...	—	—

(*b*) *Licenses.*

None.

2. COMPANIES.

(*a*) *Provisional Orders.*

Fareham	Fareham E. L. Co.	Working ...	80	30
Liverpool	Liverpool Electric Supply ...	„ ...	See *ante*	—
County of London ...	County of London E. L. Co.	Waiting ...	—	—
Southwark	„ „	„ ...	—	—
Wandsworth ...	„ „	„ ...	—	—
Oxford	Oxford Electric Co.	„ ...	600	240
Sheffield	Sheffield E. L. & Power Co.	„ ...	650	300
Woking	Woking Electric Supply Co.	„ ...	See *ante*	—

(*b*) *Licenses.*

Ogmore Valley ...	Ogmore Valley E. L. & Power Co.	Working ...	140	—

1893.

1. LOCAL AUTHORITIES.

(*a*) *Provisional Orders.*

Barnet	The Local Board	Waiting ...	—	—
Beckenham	„	„ ...	—	—
Bridgend	„	„ ...	—	—
Colchester	The Corporation	„ ...	—	—
Eccles	„	„ ...	—	—
Hackney	The Board of Works	„ ...	—	—
Hammersmith ...	The Vestry	„ ...	—	—
Islington	„	Sanctioned	—	—
Poplar	The Board of Works	Waiting ...	—	—
Partick	The Commissioners of Police	„ ...	—	—
Taunton	The Corporation	Working ...	440	165

PROVISIONAL ORDERS AND LICENSES—*continued.*

(*b*) *Licenses.*

District.	To whom Granted.	Present State.	Engines I.H.P.	Output, K.W.
Taunton	The Corporation	Merged ...	—	—
2. COMPANIES.				
(*a*) *Provisional Orders.*				
Altrincham & Bowdon	Manchester Edison-Swan Co.	Waiting ...	—	—
Newcastle-upon-Tyne	Newcastle-upon-Tyne El. Supply Co.	Working ...	1,100	600
Newmarket	British E. L. Co.	Waiting ...	—	—
Reading	Reading Electric Supply Co.	Working ...	160	36
(*b*) *Licenses.*				
Pontypool	Pontypool E. L. & Power Co.	Waiting ...	—	—

General WEBBER: It has been suggested, Sir, that I should ask this meeting to vote you, with acclamation, their thanks for the interesting and excellent Address with which you have favoured us. I know that you would probably prefer that we should restrict our applause to the minimum, but I cannot allow the opportunity now afforded me, to escape without asking the meeting to remember that this year we are receiving from you, as representative of that great family of Siemens, to which Mr. Preece has referred, a *resumé* of subjects with the development of which most of them have had much to do. You have told us of things which no doubt are in all our minds, in a way in which we have rarely heard them put together in the past.

There is one thing, however, which gives a strong personality, and which impresses our minds after hearing your Address—it is one which comes home to my heart, and one which perhaps many here present are not aware of: we have had from you the address of a man whose character has been formed, and whose education was commenced in early life in the army of the greatest nation

of Europe. In that army, I believe, you received a training which I consider second to none. Under the fire of the enemy you had imparted to you that strength of mind and purpose that has never left you since we have known you on this Council. And for your distinguished service on more than one occasion, you have received the much-coveted decoration of the Iron Cross. I look back along that long avenue of time, lined on either side with well-remembered faces of the past members of this Council. I wish to remind the meeting that you and your distinguished uncle are not the only representatives of your family to whom we owe much, but that another name is still held in high esteem, especially by those who early sat on this side of the table—I refer to Carl Siemens. To him also are, I believe, owing many of the results of the work done not only abroad, but also by that firm of which you are now the head on this side the North Sea. It would have been a great pleasure to us had he been able to have been here to-night to hear the Address of his able nephew. If you have not referred to one subject which comes home to some of us, and to which your uncle, William Siemens, gave so much attention, it has been no doubt for want of space. I hope that this year may show that electrical science is going to do something for that industry which we all know in this country is nearly "stone-broke"—I mean agriculture. Your uncle did much in the initiative for encouraging and helping horticulture through the aid of electricity, and we hope that during the period of your year of office there may be something done in that direction, and that we shall hear more of what is likely to be done to help the farmer, whose sad condition we all deplore. I beg to move—"That the thanks of the Institution be given to "the President for the admirable and very interesting Address "just delivered by him, and that he be requested to allow its "publication in the Journal of the Institution."

Professor H. Robinson: I have much pleasure in seconding the resolution so well moved by General Webber, but I feel confident that it requires no words from me to commend it to the meeting. I know that all who have heard the President's Address will say that it is of deep interest, both to the older as well as to

the younger members. The Address is stamped with a broad view of the requirements of the case, both with regard to the present and the future; and whilst older members of the Institution will appreciate the scientific and practical views expressed by the President, I commend it very strongly to the attention of the younger members, particularly with reference to that part that deals very clearly and with very much detail with what is of all importance, namely, the early training of those who intend to follow our profession. I am satisfied that no Address has been presented to the profession so worthy of being studied carefully by both the older and younger members. It is my pleasure to second this proposal of General Webber.

Mr. Preece: I have great pleasure in putting this resolution to the meeting, and I hope you will carry it by acclamation.

The resolution was then carried unanimously and enthusiastically.

The President: Ladies and gentlemen,—I can only tell you that I am extremely pleased with the kind way in which you have received this Address, and shall have great pleasure in permitting its publication in the Transactions; I will then add that table to which I have alluded. I have intentionally in the Address spoken on general practical subjects, not going into any detail, and not treating them from a scientific point of view; and I am very much gratified that I seem to have satisfied you by dealing with the matter in this way.

I have to report that the scrutineers declare the following candidates to have been duly elected:—

Foreign Members:

Prof. Paulo Benjamin Cabral.
Prof. H. S. Carhart.
Samuel Insull.
F. Jaynes.
Dr. Claudiano Luiz Pinna.
Arnold von Siemens.
Wilhelm von Siemens.
Carl Albert Unbehaun.

Member:

Lester Bruce Betts.

Associates:

Robert J. Anderson.
Albert Barron.
Francis James Blake.
William Boyd.
Christopher J. Cummins.
J. Birnie Evans.
Robert Charles Frewer.
J. K. Gibson.
Ernest Alfred Giles.
Alfred T. Hailey.
Alfred John Harrison.
Clifford Hawkes.
Joseph Alexander Jeckell.
Walter C. Lang.
H. A. McCausland.
Herbert Henry Oswald.
David Paisley.
Arthur Portelli.
William Pearson Richmond.
Thomas Rooke.
Sydney G. C. Russell.
Arthur Leighton Stevens.
Roland H. Streatfeild.
Howard George Tozer.
Alfred T. Warren.

Students:

Arthur Anstruther-Thomson.
Noel Broomhall.
Sidney Phillips Doudney.
George F. Herron.
David Martin.
Hugh Bernard Maxwell.
Charles Stanley May.
N. B. Rosher.
Frank John Rynd.
George Swetenham.
Charles Percy Taylor.
Ralph Waldo Webster.
George Edward Wright.
R. J. C. Wood.

The meeting then adjourned.

The Two Hundred and Fifty-eighth Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, January 25th, 1894—Mr. ALEXANDER SIEMENS, M. Inst. C.E. (President), in the Chair.

The minutes of the Ordinary General Meeting of January 11th, 1894, were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Arthur Bergtheil.	Edwd. Alfred Gimingham.

Allan Plucknett.

From the class of Students to that of Associates—

Herbert J. Allen.	Herbert Lewis.
Oliver Freeman.	Sidney B. Roth.

John Addison Russell.

The PRESIDENT announced that Mr. Arnold von Siemens, the eldest son of the late Dr. Werner von Siemens, had been appointed Local Honorary Secretary and Treasurer for Germany.

Mr. H. E. Mitchell and Mr. F. V. Andersen were appointed scrutineers of the ballot for the election of new members.

The PRESIDENT: I now have much pleasure in calling upon Mr. Preece to read his notes on a trip to the United States and to Chicago in 1893.

NOTES OF A TRIP TO THE UNITED STATES AND TO CHICAGO—1893.

By W. H. PREECE, C.B., F.R.S., Past-President.

Mr. Preece. In 1877, together with Mr. H. C. Fischer, I made an official and thorough inspection of the telegraphic system of the United States and Canada, and the lessons of that journey were reported to this Institution on February 13th, 1878. The results of that trip were the introduction of the telephone, the practical application of quadruplex working, the adoption of sound reading in our telegraph offices, the disappearance of the Morse recorder, and the more general assimilation of the methods of working in the two countries.

In 1884, as a member of the British Association, I again visited Canada, and made another tour through the States, reporting my observations to the Institution on December 11th, 1884. The chief result of this second trip was the introduction of the multiplex system of working of Mr. Delany, now so much in use amongst us, and doing splendid service with many of our chief towns; hexode working, six messages in any direction are simultaneously transmitted between London, Brighton, Bristol, Birmingham, and other commercial centres. The telephone was found fully developed, and firmly rooted as an invaluable aid in domestic and business requirements. The electric light was making great advances, especially as the illuminant of public streets and ways, to the great advantage and safety of the public, but electric railways and the transmission of power were only just looming in the air in an extremely tentative and experimental stage.

Now I am able to report another tale of a ten weeks' trip taken in August and September last over much the same ground, but with two *pièces de résistance* thrown in—a visit to the great "World's Fair," and the holding of an Electrical Congress at Chicago.

I.—TELEGRAPHS.

The telegraphic system in the United States is in the hands ·o great private telegraph companies, the Western Union ·ph Company and the Postal Telegraph Company.

The Western Union Telegraph Company, which is by far the larger of the two, is a gigantic undertaking. It is a congerie of at least 500 other companies which have been purchased, absorbed, or amalgamated from time to time; and it is also closely connected with virtually all the railways in the States. This connection with the railway companies gives it a very prominent and commanding position over its rival. In order to show the progress made since 1884, and the present condition of the business, I give the following table:— Mr. Preece.

Particulars.	1884.	1893.	Great Britain, 1892.
Miles of poles and cables	145,037	189,936	33,689
Miles of wire	450,571	769,201	207,231
Offices	13,761	21,078	8,537
Messages	42,076,226	66,591,858	72,302,556
Capital	$80,000,000	$123,000,000	£10,130,820
Receipts	$19,632,940	$24,978,442	£2,486,791
Expenses	$13,022,504	$17,482,405	£2,470,839

The Postal Telegraph Company is a very much smaller concern. It has virtually come into existence since my previous visit, for when I was last in the States it had just commenced its operations, and it only possessed 1,500 miles of line and 4,260 miles of wires. It is a company which has been promoted, not so much to attack the Western Union Company, as was the case with all previous competing lines, but to establish a collecting company for the cable business which is in the hands of the Commercial Cable Company. The present position of the Postal Telegraph Company is as follows:—

Miles of line	15,997
Miles of wire	99,664
Offices	2,664*
Messages	9,335,291

The enterprise in telegraph work is evident at once on landing in New York. Every passenger on landing at the dock stage is

* Of this number, 860, or nearly one-third, are situated out of the States, in Canada and elsewhere.

MR. PREECE. approached by a messenger from one or both companies, soliciting messages; and on all the stages, except that of the Cunard Company, one or other of the telegraph companies has succeeded in establishing an office. The business done at these offices is very great, as, when facilities are thus given to passengers to send messages, nearly everyone wires home his or her safe arrival. This enterprise is evident everywhere. The blue and white sign of the Western Union Company, which is extremely prominent, is found in every hotel, at all railway stations, and in large cities, and is as abundant as the Post Office sign is in England. At Long Branch, the Brighton of New York, where I spent two or three very pleasant days, there were no less than 19 offices belonging to the Western Union Company, and all paying.

There were 20 offices in the World's Fair alone, and 70 hotels in Chicago have Western Union offices in them.

Competition is intense, but there is no war of rates. A general tariff has been agreed upon, and the only rivalry that exists is in the collection and transaction of business. Dividend-earning being the chief end aimed at, only paying commercial stations are properly served. Social and domestic telegraphy is practically ignored, and sparsely populated districts are very inadequately provided for. Hence in the United States telegraph business is neither so general nor so cheap as it is with us. The average price received per message is $15\frac{3}{4}$d., as against 7·7d. earned by us. On the other hand, however, it must be remembered that their mean distance is far in excess of ours.

Construction of Lines.

I inspected considerable lengths of the line work constructed by each company, and drove over many miles of a new road line passing through Connecticut.

In this direction American electrical engineers have been very much behind us. They have not built their lines so solidly, nor have they followed true engineering principles in the same way that we have.

As a rule, their old lines are extremely irregular, being badly constructed with poles that we in England would not look at.

But recently, owing to the difficulty in finding fresh routes, the growth of the number of the wires, and to the absolute necessity for accuracy of workmanship for securing silence on telephone lines, great improvements have been made, and some of the trunk lines put up by the telephone companies, and the new trunk line put up by the Postal Telegraph Company, will compare very favourably with our best modes of construction. Mr. Preece.

The telephone line to which I have alluded above consists of 16 arms, each carrying 10 wires, or 160 wires in all; the poles are 60 feet high, and are placed 100 feet apart. The arms are of pine, and their scantling is 3½ inches by 4¼ inches, and they are 10 feet long. Owing to the use of wooden pins they are bored with holes 1½ inches in diameter. This weakens the arm, and I observed two instances where arms were broken. A 6-foot arm bored for four insulators costs 15 cents, which is very cheap compared with the price we pay. But they are undoubtedly weak, and not to be compared with the oak arms that we use.

As a rule, the poles number 40 to the mile. They are generally of cedar, but sometimes of chestnut. The cedar poles come from Canada and Michigan. Each 25-foot cedar pole costs $2.25, and is said to last 15 years without preparation. The chestnut pole is a little cheaper, and it lasts only 10 years. It is extremely irregular in shape.

American engineers do not adopt the same plan that we adopt in the erection of arms. They are fixed any way, but generally on the modern lines they alternate on each side of the pole. This is done under the impression that it adds strength to the line. I do not know why it should. (We invariably fix the arms on that side of the pole facing London.) Every fifth pole is earthed as a protection against lightning. (We earth-wire every pole.) Stays are very little used indeed, but on new lines they have longitudinal stays in the direction of the wires, one end being fixed at the foot of one pole, and the other end at the top of the next pole. These are called "head guys," and are frequent. Iron poles are used only for electric railways. These are very substantial, and look very well. They are made in three sections of simple iron tubes, either 6, 5, and 4, or 5, 4, and 3 inches in diameter respectively.

Mr. Preece. Pole roofs are not used as with us, but the poles are tapered off to throw off the rain.

Neither the Western Union nor the Postal Telegraph Company adopt any system for preparing their timber to resist decay. My attention had been called to a system of artificial seasoning called "wood vulcanising," and it was reported that this system had been adopted by the Western Union Company. I found this was not true. The Western Union Company had experimentally tried the system on some wooden troughing, employed for the protection of their pneumatic tubes underground; but the process was so expensive, and the advantages so doubtful, that they do not apply it to their poles or their arms.

Copper wire is very much used on telegraph and telephone lines. I saw in the Exhibition at Chicago a form of wire called "tempered copper." This is said to be extremely strong and hard, but it is evidently an alloy of copper, for its resistance is high. I was surprised to find that a compound wire 1.7 ohms resistance per mile, put up by the Postal Telegraph Company in 1883, is still in use, and working well. Our experience of the durability of this wire was disastrous.

Underground Work.

Underground work was scarcely started in the States in 1884, but now, owing to peremptory legislation on the part of the municipalities, it has made very rapid progress. Underground work in the cities of the States has become general, with great advantage to the public, and also, as they have come to acknowledge, to the companies themselves. The only exception to this rule that I heard of was at Boston, where complaint was made that their underground system had been much disturbed by "wash-outs." These "wash-outs" are freshets, or great floods, tearing up the line and carrying away the pipes and wires.

The system of underground work adopted by the telegraph companies in America does not differ much from that adopted by us, excepting that they do not use gutta-percha, owing to its high price. They are using very largely a cable similar to the Fowler-Waring cables, and also kerite-covered wire. Kerite is a form of vulcanised india-rubber.

Offices. Mr. Preece.

Not much change has been effected in the mode of fitting up offices. Glass of the best quality is used very much indeed: doors, partitions, boxes for the collection of messages, are all made of thick glass. This looks very clean and nice, and is certainly effective.

There is an extremely efficient mode of collecting and distributing messages in the Western Union offices at New York and Chicago. Endless cords are kept in motion by means of small electric motors, and these cords transport small metal carriers somewhat similar to those we use in our pneumatic tubes. Before leaving New York I saw an improvement on this by which messages can be picked up as by the finger and thumb from the desk in front of each operator. They also have in use a system by which messages, envelopes, slips, &c., are conveyed by broad continuous leather belts, 8 inches wide, kept in rapid motion by motors, and upon which the messages, &c., are laid, and carried to the point desired.

Each company has adopted a uniform and pretty-looking box for its office in the hotels. American hotels differ from ours in this: The hall of an hotel is usually open to the public, and no hotel that I entered was unfurnished with a telegraph office. I have mentioned that there were 70 hotel offices in Chicago. In fact, hotel proprietors court the presence of a telegraph office. Space is usually accorded free, and board is also provided for the operator. In some places, like the "Palmer House" Hotel at Chicago, which is a great business centre, a very high rent is demanded; but, generally speaking, no rent at all is paid. At the hotel I stayed at in Chicago—"The Lexington"—each company had an office in the hall; the rivalry that exists between the two companies taking the form of each striving to work with the louder sounder. The louder was that of the Postal Telegraph Company, and when I asked the operator why he allowed his instrument to make such a row, he replied, "We must beat the "Western Union Company anyhow."

At Fort Sheridan, a military station about 20 miles away from Chicago, the Western Union Company opened an office, although

Mr. Preece the place contained only 1,000 soldiers. The office was worked by the soldiers, and I was assured by the company that they found it pay well.

The common system in the States is to tile the floors of their telegraph galleries, and not to board them. Fireproof channels, or conduits fitted with slate tops, are arranged about the office for the distribution of the wires. Lockers for coats and hats are roomy and well made, and ample in the supply. At Chicago they are of open ironwork, very neatly made, 6 feet 6 inches high, and 28 inches by 8 inches in sectional area. Four men, each of whom is supplied with a key, use such a locker. Great advantage is said to arise from the use of these open lockers in wet weather, and they are worth our own consideration.

The use of bicycles for messengers is very prevalent in the States.

Batteries at all the principal offices in the United States are gradually disappearing. The current for working the circuits is being supplied from dynamos, or from the electric lighting mains. In New York from 30,000 to 40,000 cells have been replaced by dynamos. At Boston 10,000 cells, which cost probably £4,000 per annum to maintain, have been replaced by current derived from the electric light mains at a cost of £600 a year. It must be remembered that the American telegraph circuits are worked entirely on the closed-circuit system. They use immense cells, and their cost of maintenance is excessive. We cannot compare their system with ours in this respect, for we use open circuits; and the maintenance of our batteries is certainly, cell for cell, not more than one-fourth or one-fifth that of the United States form of battery.

In New York the Western Union Company have a special plant of 51 small dynamos. In Chicago they have 46. The Postal Telegraph Company in New York are also using dynamos, and in their new station which is being built they are supplying what they believe to be an improvement on the system adopted by the Western Union Company.

We have shown in England that the use of dynamos, owing to the variation of current, is not suitable for high-speed

working, and I much prefer the plan that we have adopted with so much success in working our Continental circuits—namely, the use of accumulators. Accumulators have an immense advantage over dynamos: they store up energy, so that in the event of any accident or breakdown of machinery the accumulator maintains the circuits working. The accumulator is not in motion. There is no machinery to fail or to break. There is nothing to stop, and little to get out of order. But the chief advantage of the accumulator is the absolute steadiness of its voltage. There is also economy in capital expenditure, and I am quite convinced that the Western Union Company in New York would have effected considerable economy if they had used accumulators charged by the electric lighting plant, instead of supplying the elaborate series of engines and dynamos now working their circuits direct. Mr. Preece.

At Boston and other stations a very well made and well designed motor-dynamo is supplied by Messrs. Crocker-Wheeler. They are primarily motors worked on the 110-volt electric lighting service, driving a small dynamo, and they transform this down to a voltage which will charge any number of cells required. This system is in use by all the telephone companies, and, as I will point out when speaking of telephones, the service is much improved by the use of accumulators thus charged.

Apparatus.

I observed little or no progress in the form of apparatus used. In neither company has there been any advance made on the systems in use in 1884. Duplex and quadruplex working are principally relied upon, while on the long-distance lines Wheatstone working is gaining ground, and being much more used. The only novel mode of working that was brought to my attention was a system of working cables automatically. This system has been threshed out by Mr. Wilmot at Waterville, and adopted by the Commercial Cable Company, but it has been very much improved upon by Mr. Delany, the inventor of our multiplex system.

Typewriters have become quite common. The rule is for an

Mr. Preece. operator to have his own machine. The Postal Telegraph Company use this system more than the Western Union Company. The latter company employ it invariably for their Wheatstone and other news circuits, but the Postal Telegraph Company use it very largely on all circuits; and I watched many operators taking off messages by ear and typeprinting them at the same time, and in all cases the typewriting machine held the sounder well in hand as regards speed.

The working of the Wheatstone system between New York and Chicago is admirable. The grand total of messages handled in one day on this circuit is certainly astonishing. 4,211 messages have been passed between these two places on one circuit in a day—a number that we can scarcely hope to rival.

The reason for this is not the greater speed at which the apparatus is worked—for the speed is less than ours—but to the fact that the business day in the United States extends over a much greater number of hours than with us. The business day in New York commences three hours before that in San Francisco, and the business day in San Francisco extends for three hours beyond the business day in New York. Hence the business day, which in England scarcely extends telegraphically to four hours, in the United States extends probably to 12 hours. Thus the number of messages handled is much greater per day than with us.

The advantage of Wheatstone working to the company was illustrated while I was there. On August 29th a cyclone in the eastern part of the States prostrated the poles and wires for miles throughout half a dozen States. Three Wheatstone circuits were maintained working—and working badly—between Chicago and New York by means of repeaters at Buffalo and Pittsburg, but on these three circuits 8,693 messages were handled. This was the only means of telegraphic communication between the Eastern and the Western States. Curiously enough, the new and strong long-distance telephone line was not broken down.

On August 18th, while I was there, I took down as having been sent between 8 a.m. and 5.30 p.m.—forwarded, 1,272; received, 1,889. This work was handled on two circuits, with an average speed of 190 words per minute.

The Wheatstone system in the States is much more extensive in the West than in the East. It is giving such good service that it will probably receive considerable additions this year. Mr. Preece.

It must be remembered that between Chicago and San Francisco we are dealing with a distance of 2,500 miles, and on this circuit they were working when I was there at the rate of 110 words per minute.

I observed a very high rate of working on some of the quadruplex circuits. I took down these figures at Boston—

Forwarded	686
Received	521

This was an ordinary day's work. On another circuit, between 8.30 a.m. and 11.30 a.m., in Buffalo, the numbers were—

Forwarded	126
Received	140

On one side of the quadruplex only.

I noticed at the Chicago Exhibition, in the French exhibit, a new adaptation of multiplex working by Mons. Mercadier, who showed in operation 12 working sides. But the working, although interesting, was poor. The reading was done by telephone, and each branch was selected by the sounding of a particular note. The apparatus is not yet in anything approaching a practical stage, but for short lines something may some day come out of it.

Pneumatic Tubes.

The Western Union Company have not extended their system of pneumatic tubes greatly since my last visit. The Postal Telegraph Company are about to use pneumatic tubes for the distribution of their internal work in their new building on a plan somewhat similar to that which we use at our central station.

The only novelty in pneumatic tubes that I saw was that on trial between the Post Office at Philadelphia and a sub-office in Chestnut Street. This is a line of two pipes $6\frac{1}{8}$ inches in diameter and 5,792 feet in total length—that is, a distance between the two offices of 2,896 feet. The carriers are metal cylinders whose inside dimensions are 16 inches long and $5\frac{1}{4}$ inches in diameter. They weigh 6 lbs. each, and carry 120 letters. The

Mr. Preece. carrying capacity of the line is said to be 180,000 letters per hour, but I think this is exaggerated; the time taken by a carrier in transit is 55 seconds, and the air pressure is maintained at 7 lbs. per square inch.

The line has been working since February 17th, and it has been used for the transmission of letters, the whole service to this particular sub-office being done through the pipe.

The pipe is continuous, and a current of air is constantly flowing through it. Twenty-five horse-power is absorbed in maintaining this current at the pressure required, and the carriers are said to move at the rate of 40 miles an hour. Twenty-five carriers are in use.

Unfortunately, while I was there the tube was out of use, for the boilers had broken down. These boilers belong to the Post Office Administration, and were not under the control of the contractors who are carrying out the experiment.

It is merely an experiment, but it is an experiment that has been carried out in a very practical manner, and they are threshing out a question that may be of importance.

They find that the tube used is too small for their purposes, and they are going to use in future an 8-inch tube.

Distribution of Time.

A feature of considerable interest and novelty is the distribution of time by the Western Union Company. Correct time is received every day at noon from Washington. The time current lasts one second. Time balls are dropped at Boston, Newport, Woods' Holl, New York, Philadelphia, Baltimore, Washington, Fortress Monroe, Savannah, New Orleans, and Havanna. This current is also distributed by the Western Union Company to subscribers in the principal centres. In New York there are 1,100 subscribers, in Chicago there are 1,837, while in the whole of the Western District of the company there are 7,963 subscribers. Each of these subscribers has a special wire upon which the time currents are sent from a master or a controlling clock. The Western Union Company also furnish synchronous self-winding clocks to the subscribers, which are controlled and regulated daily by these

time-signal currents. They are wound by current automatically every hour. Mr. Preece.

The rates for this service are not excessive. Each subscriber is charged \$2½ per month, while large buildings using five or more clocks get the time signal supplied at \$1¼ per clock per month.

The standard time adopted in 1883 is virtually Greenwich time. It is divided into four sections. The following table will show how far these differ from Greenwich mean time and from each other:—

W. Long.	Centre.	Actual Time.	Name adopted.
0°	Navigators' time (Greenwich)	Noon	Greenwich time.
75°	Washington Meridian ...	7 a.m.	Eastern time.
90°	Chicago Meridian	6 a.m.	Central time.
105°	Denver Meridian	5 a.m.	Mountain time.
120°	San Francisco...	4 a.m.	Pacific time.

Thus the minutes and the seconds are the same as with us. There is no necessity to alter one's watch.

Hefner von Alteneck proposes to place clocks in the circuit of an ordinary glow lamp, and to wind and control them by a slight change in the current made at the central station once a day. It is surprising what can be done by electricity when it is laid on in a house and served from a central station.

Von Alteneck's system was exhibited at the World's Fair.

Conclusions.

It is quite impossible to inspect the telegraph system of the United States and compare it with our own system without drawing comparisons between the way in which the work is done in the two countries. The result of my previous visit was to confirm my view that we do our work better in England than they do in the States. Our apparatus is better, our speed is higher. Messages are handled with greater reliability. A message can be sent and its reply received with certainty in an hour in England. I fancy such rapidity would astonish the users of

Mr. Preece. the telegraph in the States, except those in such busy centres as New York and Chicago, and generally the speculative branches of the community.

The domestic telegram scarcely seems to have reached the United States, and this is owing, probably, to the fact that the districts of private residences, the small towns, and the villages do not possess telegraph offices, unless they are supplied by the railway company at the railway station, or by the Western Union Company, who do the work for the railway company.

I fail to see any superiority in the manipulation skill of American operators. They certainly have not made the same advance in technical education that we have, and altogether it may be said that the management of the telegraphs in the States in the hands of private enterprise does not compare favourably with the management of the telegraphs by the State at home. At the same time, it must not be assumed, because the Government have advantageously taken the telegraphs in hand at home, that such a process would be possible in the States. In my opinion, it would be absolutely impossible. The Civil Service of the States is in a very chaotic condition. The principal appointments are four-year appointments only, and are filled politically. The principal postmasters come in and go out with each new President. We in England scarcely consider that a postmaster is fit to be a postmaster until he has had many years' experience of the working of the Post Office system. In the States a man is made a postmaster because he has been a political supporter. At one or two offices I found the new Post Office officials absolutely ignorant of simple facts they ought to have had at their fingers' ends. A business like that of telephones or telegraphs can only be conducted properly by those who possess a considerable amount of enterprise, and who look primarily to the necessities of the community. The reason why our post offices and our telegraph offices at home work so well is because the public exercises such a useful and such a determined supervision over the work. The free opening of the Press to complaints; the criticisms to which the public service is subjected; the readiness with which members of the House of Commons ask

questions—though at times, perhaps, irritating and vexatious—are undoubtedly good for the service, for they keep us all alive. Such a state of affairs is impossible in the States. Mr. Preece.

The Government of the United States must first reform its Civil Service, and when it gets officials into the service whose tenure of office is secure, and whose zeal is as unquestioned as it is in England, then there will be some chance of their Government acquiring the telegraphs; but under existing circumstances the acquisition of the telegraphs by the Government of the United States would amount virtually to the deterioration of the service. The commercial management is at present, as I have pointed out, characterised by great energy. I do not, however, acknowledge that they show greater energy than we do in England. Competition may make it more conspicuous, but it is not more reaching. Our speculative business, stocks and racing, is done as well as theirs.

The telegraph management at home is characterised in all particulars with similar energy to that which I observed in the States; and I come back without any views or wrinkles which I think could be impressed with advantage on the commercial or technical management of our system at home, unless it be the encouragement of offices in hotels, for it is found everywhere that a telegraph office at one's door prompts the desire or want to telegraph.

The capital of the Western Union Telegraph Company was in 1877 $22,000,000; that of the British Post Office was £10,000,000. The capital of the former is now $123,000,000, while that of the latter remains virtually the same. Scarcely a single vestige of the old telegraph companies' systems purchased by the State in this country now remains. Whence, therefore, this splendid system of cables, underground lines, and new pole lines in this country, spreading everywhere, and transacting an annual business of £2,500,000, instead of the £600,000 handed over to us? It has all been paid for out of revenue! The Government keeps no capital account.

How do we do our work? The proof of the pudding is in the eating thereof. The criterion of telegraph-working is rapid

Mr. Preece. despatch. "Time is our only competitor," said Dr. Norvin Green. The time occupied in its transit from the hands of the sender to those of the receiver is the pudding. The whole of the messages arriving in Newcastle on the morning of January 20th were examined and analysed. The mean time of transit from all parts of the United Kingdom averaged 7·8 min. A similar examination at Glasgow on January 15th gave a mean result of 8·7 min. This cannot be beaten, and it certainly will not be believed. The late Mr. Patey was once asked why express telegraph service at higher rates was not introduced in England. His answer was, "All our messages are express already."

II.—Telephones.

The business of telephony in the United States has made gigantic strides since I visited that country in 1884. The following table will show the position of the industry then and now:—

—	1884.	1893 (January 1st).
Miles of wire	115,255	440,793
Miles of underground wire	*Nil*	91,463
Telephones in use	325,574	552,720*
Telephone subscribers	123,625	232,140
Number of connections between subscribers and exchange ...	215 millions	600 millions (est.)
Telephone exchanges	1,325	1,351
Staff employed	4,762	9,970

It will be seen that there is a very small increase in the number of exchanges opened. This is owing to the fact that hitherto there has been a tendency to centralise the exchange work; and while many exchanges have been abandoned, the small increase is due to the fact that many new exchanges have been opened.

* This is the total number of transmitters and receivers. According to our system of reckoning, where the two together are considered as one instrument, the number given should be divided by two. Thus for comparative purposes it may be said that the United States has 276,360 telephones in use.

It will also be noticed that in the States they have gone in Mr. Preece very largely for underground work. This has been forced upon them by municipal action. In addition to this, the companies themselves have been compelled by the indifferent working of their systems to fall back upon the metallic circuit, and now there are 23,053 metallic circuits in use. In New York 62 per cent. of the circuits are metallic, in Buffalo 77·84 per cent., in Boston over 50 per cent., in Chicago 20 per cent., and in Brooklyn 60 per cent.

The business of telephony in the United States is a gigantic monopoly in the hands of the American Bell Telephone Company, whose headquarters are at Boston. This company owns more than one-half the stock in every telephone company in the States. It holds itself the whole of the stock of what is commonly known as the Long-Distance Telephone Company, but which is really entitled the American Telephone and Telegraph Company, and thus by having control of the stock in every company it maintains the power and monopoly. The advantage of this monopoly is the establishment of a uniformity of working and practice that is highly and extremely beneficial. The form of apparatus used, the mode of working, the details of construction, and all the methods in use are dictated from Boston. The result is little or no friction; and while each independent company is self-managed and self-contained, nevertheless it is subservient to the direction and control of headquarters at Boston. There is no divided responsibility in the United States. Every town has but one system. The result is that the service is thoroughly and perfectly performed. In those parts of the country where metallic circuits have not yet been adopted there may be defects in working, but these are rapidly being removed, for the benefit derived from metallic-circuit working is being felt everywhere in the United States.

Exchanges.

The modes of working may be divided into three classes—

(*a*) That dealing with local subscribers alone working upon a single exchange;

Mr. Preece.

(*b*) That dealing with trunk working between exchanges in one town or district; and

(*c*) That dealing with long-distance speaking, such as that between New York and Boston, New York and Philadelphia, New York and Chicago.

I visited three exchanges at Chicago, one at Buffalo, one at Boston, and three in New York, and I looked very thoroughly into the working of each system. While I did not think that any of their local working is done any better than, if as well as, the local working on our own exchange at Newcastle-on-Tyne, there is no doubt that in their trunk working, both for inter-exchange communication and for long-distance working, they are far ahead of us in England.

The prevailing switch in the United States is the multiple board, made by the Western Electric Manufacturing Company. The largest board in the world is one which I carefully examined at the Cortlandt Street Central Exchange in New York. It has a capacity for 6,000 subscribers; it is 263 feet long, and is divided into 40 sections. One operator handles 60 subscribers. There are 260,000 holes, or "jacks," as they are called in the States; while in fitting up this switch 780,000 soldered joints were made.

It is found in the States that multiple boards can become too large, too unwieldy, and they introduce troubles of their own that have to be remedied. These defects are aggravated when there are several exchanges in the same city. In Chicago Main Exchange 25 per cent. of the business, in Harrison Street Exchange 94 per cent., is trunked out. The average trunking is 50 per cent. A multiple board is, therefore, useful for only 50 per cent. of the work done. It should be explained here that the term "trunk" is adopted in America to indicate connections effected between one exchange and another within the same area. Connections between town and town are designated "long-"distance" connections. The tendency is to depart from the principle of the multiple switch; and an extremely interesting experiment is being carried out simultaneously in Chicago, Buffalo, and New York to determine the merits of a new system of working called the "divided board." The divided board means

this: There are two boards, the one called the *answering* board, Mr. Preece. and the other the *connecting* board. The answering board contains the indicators and trunks, including those to the connecting board, and all local connections are treated as trunks through the connecting board. Thus, while each operator at the answering board attends to and answers only her 60 subscribers, and is able still to control all the trunk wires, the local spring jacks are duplicated on the connecting board, which may contain one, two, or three complete sections, as the case may be, and are attended to by separate operators. All the business is thus trunked. The result is that the service performed for the subscribers for local connections is slightly retarded. On the other hand, the work done on the trunks is equally expedited. If 50 per cent. of the work done in the Central Exchange is trunk work, it is argued that, if subscribers find that one-half of their work is expedited and the other retarded, the expediting of the more important part will compensate for the retardation of the less important, and the general result will be beneficial.

The chief merit of the divided board is that it reduces the "jacks," as the switch-holes are called. Seven sections of board with 42,000 jacks would replace 40 sections with 240,000 jacks in an exchange of 6,000 subscribers. I find opinion, however, divided upon this question; but the view is very general that when the multiple switch-board exceeds a capacity of 2,500 subscribers it certainly introduces disadvantages and defects which must in some way or other be remedied.

Trunk Working.

The trunk working is wonderfully well done. In the first place, the connections between the different exchanges are very numerous. In the Central Exchange at Chicago there are 344 outgoing and 325 incoming trunks. There are 11 exchanges, and these exchanges are located as nearly as possible in the centres of the districts which they are designed to serve. The business of these offices, however, is by no means self-contained, and a very great amount of their work is in handling calls from subscribers in one exchange to subscribers in another. These are

Mr. Preece. now handled by means of 954 trunk circuits extending between the various offices; the total number outgoing from each office being as follows:—

Main	344	Oakland	68
North	34	Lake View ...	26
South	77	Harrison	59
West	74	Wentworth ...	19
Canal	63	World's Fair ...	80
Yards	61		

In Boston, between their Central Station and Tremont Exchange—an exchange of 833 subscribers—there are 27 outgoing and 33 incoming trunks.

The service between two exchanges is virtually a silent one. No question is asked, but instructions are given simply—"301 on "North 273." This is spoken on a call circuit. The trunk operator—always a male—wears a headgear telephone, receives this instruction, and carries it out without a word being said, or a second lost.

In some places the subscriber, if he wants a subscriber on another exchange, calls his own exchange as usual, and, on getting attention, says, "Tremont." He is then placed in connection with the Tremont Exchange, and he himself asks for the number he wants. The former plan is, however, the more general one, and that which is preferred.

There are always so many trunk wires available that the operator has rarely to say, "Wires engaged," or "Busy," which is the common expression. I never saw one case of the kind myself. The hourly maximum number of trunk calls between Boston (Main) and Tremont Exchanges was—

From Boston	557
To Boston	475

The former averaged 20½ per circuit.

The latter averaged 14½ per circuit.

The result is that in places like Chicago, where there are 11 exchanges, and New York, where there are 9 exchanges, the trunk working is done between them virtually as though the whole of the exchanges were centred in one big hall.

The long-distance work is done in the same way. Only metallic circuits are switched on to the long-distance lines. The incoming trunk wires end in plugs, the outgoing trunk wires end in "jacks," so that when an operator hears "351 on "Chicago 3," he simply takes up 351 plug and puts it in a Chicago jack without hesitation. If, however, all the Chicago jacks are busy—which he sees at once by the visual signal—he says, "Busy," and the caller has to wait his turn. In my experience this occurred but rarely. When the calls were heard, the connections were made as rapidly as possible for it to be done, or as rapidly as one could wish that it should be done. Mr. Preece.

In New York the Long-Distance Company and the New York Telephone Company are in the same building. A complete section of the New York multiple board is in the long-distance switch-room, so that connections are made *direct* between the long-distance lines and the subscribers. Usually a section of the multiple board in the local exchange is allotted for long-distance trunk work to the long-distance office, which may be elsewhere. It is so arranged that when a subscriber talks on a long-distance line his own circuit is entirely cut out from the local operating switch-board.

There are a great many public call offices open in every city. There are 535 in New York. They call them "public pay "stations." People pay tolls, and they come in and speak to the exchanges and get their connections through.

Long-Distance Working.

The long-distance speaking in the States is very popoular and very successful. The opening of the circuit between New York and Chicago—a distance of nearly 1,000 miles—was so successful that they immediately found it necessary to erect two more circuits. There are now, therefore, three circuits between these two places. I tested these circuits, and found the working remarkably good. It was difficult to say that it was better or worse than the working of our London–Paris line.

The tariff for the long-distance work is based upon one cent per mile for five minutes' talk. The greatest distance that I

Mr. Preece. found upon which speech was conducted was between Milwaukee and Portland, and between these places talking costs 11 dollars (44s.) per five minutes.

Rate of Working.

I found that the customers dealt with by each operator varied very much in different towns. The following table will show this :—

Town.	Customers per Operator.	
	Local.	Long-Distance Trunk.
Theoretical	100	6
Chicago	66	6
Buffalo	100	—*
Boston	70	3
New York, 18th Street	50	6
Brooklyn	66	10
New York, Cortlandt Street	60	—*

The daily calls per circuit also vary very much. The average per day over the whole country is 8·03. At Chicago on one exchange it reaches to as many as 24·3; the mean for the whole town in January was 13·6, while in July it was 12·3. At Buffalo the mean is 6. It is interesting to note that the number at Buffalo is just the same as it was when I visited that place in 1884. At Boston the average number then was 5; it is now 12·6.

While this average of 12 or 13 calls per day is not an extraordinary one, it represents great extremes in the use of telephones, which bring about complications which are at times difficult to meet. There are in the main exchange at Chicago at the present time several hundred telephones which are used more than 100 times each day. Nearly all this business is handled between the hours of 9 a.m. and 5 p.m. During the busiest hours of the day these instruments are in use almost continually. When calls are made for them, therefore, the only reply is that they are busy. As an example of this excessive use my attention was called to

* I did not record the number in these two exchanges.

the case of the Waukesha Hygeia Mineral Springs Co., telephone No. 929 South. A complaint was made by one of their branch offices that they could not reach the main office, the line always being reported to be busy. A record was made of the calls handled on this telephone, and in one day it was found to be used a total of 449 times, there having been 18 originating calls and 431 calls received. In one hour the telephone was used 51 times. This is perhaps the busiest line of which there is a record. Telephones used by railway offices, wholesale houses of all kinds, hotels, and many other places, are apparently in use almost continuously in the busy hours of the day. Many such establishments have more than one telephone, some of them having as many as six. Mr. Preece.

The subscribers per exchange in the exchanges that I visited are as follows:—

Chicago ... 10,312, divided thus:—

Main	4,912	Oakland	655
South	1,037	Lake View ...	244
North	996	Wentworth ...	46
West	903	World's Fair ...	269
Canal	434	Harrison... ...	424
Yards	392		

New York, Cortlandt Street ...	4,500
Boston, Central	3,545

The total subscribers in New York are 9,574, at Brooklyn 4,800, and at New Jersey 4,900, making a total for New York and district of 19,274.

Underground Work.

The statistics that I have given show how rapidly underground cables have come into use in the States. At the Chicago Central Exchange 76 cables, each containing 100 wires, enter the building and ascend up a shoot to the exchange room. The conductor used is smaller than that adopted by us. It is only No. 19 Brown & Sharpe gauge. It gives 47 ohms resistance per mile, and it has a capacity of 0·08 microfarads per mile. The insulation must be

Mr. Preece. 500 megohms per mile at 60° F. All cables before being used are very carefully tested, not only to see that they comply with the specification as to conductivity, capacity, and insulation, but also for what is called "cross talk," by means of buzzers.

There are no less than 14,034 miles of underground wire in New York. 160 cables, each containing 100 wires, enter Cortlandt Street building—that is, 16,000 wires enter this exchange. In Boston 91 lead-covered cables enter—that is, 10,920 wires in all, for each cable carries 120 wires.

The cables are made for 50, 60, or 100 pairs of wires. The 50-pair cables have a diameter of $1\frac{7}{8}$ inches, the 60- and 100-pair cables being 2 inches and $2\frac{1}{4}$ inches in diameter respectively. These cables are in all cases brought straight to distributing boards in a room alongside the switch-board room, and here they are brought to terminals in a way similar to that adopted by us, so that changes can rapidly be made.

Subscribers' lines are so distributed among the sections of the switch-boards that the work is distributed as uniformly as possible amongst the different operators.

The dry-core or paper insulated cable has proved to be a very great success, and is now universally adopted for telephone purposes.

Chicago.

I have given the number of exchanges and subscribers in Chicago. To provide for this service there are—

Miles of conduit	48·02
Miles of duct, or channel	433·24
Miles of cable, underground ...	106·96
Miles of wire, underground ...	17,995·53
Number of manholes	888·0
Miles of cable, aerial	65·97
Miles of wire in aerial cables ...	5,184·70
Total miles of wire in cables ...	23,180·23
Total miles of wire on poles ...	7,958·0

Switch-Boards and Indicators.

Great improvements in working have been made in consequence

of the introduction of metallic circuits. Visual signals, like those employed by the Post Office Department, are coming in. Dirt in the gear was a great source of trouble. False busy signals were frequently received. Now a third wire and an automatic restoring indicator has made the busy test reliable. The visual signals on trunk wires are assimilating the American working to our Post Office system. Mr. Preece.

Disturbances.

The disturbances in telephone circuits created by the extension of electric railways have been severely felt in many parts of the United States. We have experienced the same in London, Liverpool, Leeds, and Blackpool. But owing to the prompt action taken by the telephone and railway companies, especially in Boston, the area of disturbance has been much reduced, and the influence of electric railways on telephones has ceased to be a trouble. Of course this result is very much favoured by the rapid introduction of metallic circuits into cities; but it has also been favoured by the prompt action of the railway companies themselves. They did all that they were asked to do, and that at once. In all cases the negative pole of the dynamo at the generating station is put to earth, and the return conductors have been enlarged. Extra copper wires have been buried between the rails, and heavier conductors have been put upon the poles. The return conductor is the largest size copper wire made, viz., No. 0. The rails have been bonded together and to this return conductor; and in Boston the rails are welded electrically, which is very effective. I was, unfortunately, unable to see this electric welding in operation, for the transformer had broken down, and was in the shops under repair. I saw the whole apparatus, however. A special car is used for the plant, and the system adopted is extremely satisfactory.

The electrolytic action of these disturbing currents has been noticed not only as affecting gas and water pipes, but also the lead coating of the telephone companies' cables. I have seen several specimens of lead pipes much pitted. I have reason to believe that the remedies adopted to cure disturbance will also

Mr. Preece put a stop to what might have become an element of great danger to underground cables.

Lightning Protection.

A very efficient system of lightning protection has been introduced upon the telephone system, not so much to protect the system from the effects of lightning, as from the effects of those powerful stray currents that enter a telephone circuit when accidental contacts occur between it and electric light and electric railway conductors. Such contacts have been frequent, owing to the prevalence of overhead systems, but they are diminishing now that conductors are placed underground. They have resulted in numerous accidents, and several telegraph and telephone offices have been set on fire and the apparatus destroyed. Every telephone circuit is now protected by a fuse, or cut-out—a fine wire of great resistance, which melts if traversed by a powerful current; also by an air space protector on the same principle as the lightning arresters we use, but having carbon plates instead of brass plates; and, finally, by a small heat coil, which puts the current to earth in a very ingenious way when the stray currents exceed a certain strength. These three guards have been found quite effective. No accident has occurred where they have been used.

Rates.

The rates or rentals demanded from the various subscribers differ very much in the States. At Buffalo they charge a toll rate on each talk; they do not demand an annual rental; they simply demand a minimum amount of business per annum. This rate in Buffalo is 10 cents for five minutes' talk, and they have adopted a system of charging one-fifth of this rate for each extra minute beyond the five. The rate in San Francisco is a small annual rental for each installation, and 5 cents for each talk. A somewhat similar plan is in use at Milwaukee. But, with these three exceptions, the toll system has not found favour in the States, and at every other exchange an annual rental is demanded.

The American Bell Telephone Company are now considering

the advisability of limiting the time for talks to three minutes instead of five, of reducing the minimum toll in proportion, of making additional charges for each minute *pro rata*, and of considering a fraction of three minutes as equivalent to the whole time. Mr. Preece.

I give below, in tabular form, the rentals charged in 25 of the chief cities of the States:—

Standard Yearly Rates for Subscribers.

——	Residence.		Business.	
	Metallic Circuit.	Single Wires.	Metallic Circuit.	Single Wires.
	$ $	$ $	$ $	$ $
New York	240	150	180	100
Chicago...	175	125	125	100
Philadelphia	160	120	130	100
Brooklyn	150	...	100	...
St. Louis	...	100 120	...	60.80 100
Boston	156 160	120	110 134	96
Baltimore	120 160	78	90 160	78
Cincinnati and Covington ...	125	100	100	72
San Francisco	*72 90	*60	72 90	60
Cleveland	120	72	100	60
Buffalo	† Toll	...	Toll	...
New Orleans	...	96	...	62.50
Pittsburgh	126	84	112.50	75
Washington	120 160	100	90 160	72
Detroit	...	72	...	50
Milwaukee	‡80 90	60	70 80	50
Newark...	150	...	100	...
Minneapolis	120	72	100	60
Jersey City	150	...	100	...
Louisville	...	72	...	60
Kansas City	...	72	...	60
Omaha	...	60	...	60
St. Paul	120	72	100	60
Providence	120	60	100	48

* Also "toll" of 5 cents per conversation.

† Installation charge, $70 for first 500 messages.

‡ Rates cover installation and yearly business of 1,000 messages. $10 is charged for each additional 500 messages.

Note.—Where two rates are given in the same column against an exchange they represent different kinds of instruments furnished. In many cases single-wire rates are no longer quoted for new subscribers.

Mr. Preece. The rates vary, and are, as will have been seen, very high; but although the enterprise is in the hands of private companies, it must be noted that they have great difficulties to contend with. In a place like New York the rents and the cost of buildings is excessive. In one small exchange they pay no less than $7,000 a year rental for one floor. Taxes everywhere are enormous. Not only are they taxed by the State, but they are taxed by the municipalities. Way-leaves are excessive. In New York alone they have to pay to the company controlling the underground conduits no less than $80,000 per annum way-leave—$8 per renter for way-leave alone. The distances, too, that they have to carry their underground system in New York, in Philadelphia, and in other places are very considerable. They have been forced by municipal action to go underground. In the face of these restrictions no comparison between rentals in New York and those paid in this country can be made. The amount of the average rental in London scarcely exceeds £15 per annum. The average amount of rental throughout the country on our Post Office system is £9 10s., but in New York subscribers have to pay up to £50 per annum.

I have drawn up, with the assistance of the American Bell Telephone Company, a comparative statement showing the ratio between the subscribers and the population in 24 principal cities of the States. The details appear in the following tables :—

City Population compared with City Subscribers. Comparative Statement, January 1st, 1893. Mr. Pree

Twenty-four Cities.	Population.	Subscribers in Exchange.	Average No. of Inhabitants to each Exchange Subscriber.
New York	1,515,301	9,066	167
Chicago	1,099,850	9,684	114
Philadelphia	1,046,964	3,620	289
Brooklyn	806,343	4,439	182
St. Louis	451,770	3,561	127
Boston	448,477	5,668*	79
Baltimore...	434,439	2,116	205
Cincinnati and Covington ...	334,279	4,015	83
San Francisco	298,997	4,528	66
Cleveland...	261,353	3,182	82
Buffalo	255,664	2,240	114
New Orleans	242,039	1,471	165
Pittsburgh	238,617	3,254	73
Washington	230,392	1,845	125
Detroit	205,876	4,287	48
Milwaukee	204,468	2,561	80
Newark	181,830	1,094	166
Minneapolis	164,738	2,053	80
Jersey City	163,003	970	166
Louisville	161,129	2,556	63
Kansas City	157,984	2,581	61
Omaha	140,452	1,738	81
St. Paul, Branch of Minneapolis	133,156	1,521	88
Providence	132,146	2,948	45

It will be seen how very much these places vary. In Providence, for instance, with a population of 132,146, we find one subscriber to each 45 persons; while in Philadelphia there is one to every 289 only.

In 10 of the principal towns of our own country the results are as follows:—

* Does not include Express subscribers. With Express, 72 inhabitants.

Mr Preece.

——	Population.	Subscribers in Exchange.	Average No. of Inhabitants to each Exchange Subscriber.
London	4,263,294	6,700	636·3
Liverpool	513,790	4,500	114·1
Manchester	510,998	2,300	222·1
Glasgow	669,059	3,200	209·0
Edinburgh	264,787	900	294·2
Plymouth...	85,610	300	285·3
Birmingham	483,526	1,200	402·9
Leeds	375,540	1,300	288·8
Hull	204,750	400	511·8
Newcastle...	192,205	1,300	147·8

The telephone in the United States is essential to the business man, and its price is compared with that of an office boy. Labour in the States is expensive, and an office boy costs more than a telephone subscription.

The present generation in America has grown up with the telephone. It has become a factor of business, and absolutely essential to the transaction of that business. Its use has passed its climax; it has reached its normal stage. There is no touting for business; business comes. Every new office must have it. The working is excellent, and they are alive to the necessity of maintaining its efficiency at the very highest point. Education is complete, not only of the staff, but of the customer. The apparatus itself is being perfected. Uniformity of practice is being introduced under the operation of the paternal control at Boston, and the influence of technical education and of technical institutions is being felt everywhere.

I find a group of highly educated, clever young electricians being engaged and encouraged by the telephone companies. New blood is being introduced, and great zeal and activity are shown.

III.—The Electrical Congress.

Two Congresses were held at Chicago—the one, a general one, to which all electricians were invited; and the other, called

"The Chamber of Delegates," to which nominees from the different Governments were sent. The latter was the more important of the two, but each secured considerable attention, and they were distinctly great successes. The following extract from an American technical journal very fairly summarises the results:— Mr. Preece.

"*The Chicago Congress.*

"The much-talked-of International Electrical Congress is now " a thing of the past. Its record may be briefly summarised by " saying that the attendance was good; that it was truly inter-" national; that there were just about enough papers; that some " good work was done; that the social features were enjoyable; " and that, while the general management left much to be " desired, the Congress itself was a success—not quite as grand " a success as we should like to have seen, but, nevertheless, " a success. Among the papers read were a few which created " unusual interest, and some which will, doubtless, become " standards of reference. The papers and discussions were of " such a character that the published volume of the proceedings " will be interesting reading, and will become a book of reference. " The foreign attendance was such that the Congress became " truly an international one. Among the foreign countries " represented England took the lead in numbers, and especially " in papers read, and in the discussions. Germany and France " came next. That it was an international assembly was shown " by the fact that the French language was freely used in papers " and discussions, the only reason why German was not used " being that educated natives of that country almost always " understand and speak English. Thanks to a few energetic, " experienced, and willing members and exhibitors, the social " features were not entirely omitted. The social events that did " take place were enjoyable, and will be long remembered by " those who took part."

The Congress met on August 21st, at least 500 being present.

Professor von Helmholtz was appointed hon. president; Professor Elisha Gray, chairman.

Mr. Preece. Each principal European country had a vice-president, and I had the honour of being selected to represent England.

The Congress was divided into three sections—

A. Pure theory.

B. Theory and practice.

C. Pure practice.

Some excellent papers were read, and good discussions ensued. The most prominent subjects dealt with were the transmission of power to great distances, and general preference was shown for alternating-current systems. The work being done at Niagara excited general interest, and some of us visited these works afterwards, with great profit and pleasure.

Professor Ayrton read a very able paper on the variation of arc lamps, so much used in America; while much interest was created by the reading of a paper by Professor Silvanus Thompson on "Ocean Telephony," a possibility in the future. My paper on "Signalling through Space" also created much interest.

Perhaps the most useful result of the Congress was the bringing together of such an international mixture of electricians, making friendships, allaying jealousies, and breaking down national prejudices. Electricity is the only branch of science which has but one language, and it is now quite cosmical in its character.

Congresses do infinite good in promoting friendliness among nations.

Chamber of Delegates.

The object of this meeting was really to consummate the work done by the British Association and by the Board of Trade, and to secure the official sanction of the United States Government to the units selected and adopted in England. This was done, and the report of the Chamber gives international support to the proposed legalisation of the ohm, volt, farad, ampere, watt, and joule, as defined by the Committee of the Board of Trade. There is no doubt that all European Governments will now accept these decisions.

A new unit was adopted, viz., the "henry," a unit of induction, which was sometimes called the "quadrant," as defined in

Paris in 1889, and sometimes the "secohm," as proposed in England. The acceptance of the name "henry" pleased the Americans very much, for their nationality has hitherto been unrepresented among the celebrated electricians whose names have been applied to the standards of electrical measurements. Germany, Italy, France were represented by Ohm, Volta, Coulomb, and Ampere; while England absorbed no less than three, viz., Faraday, Watt, and Joule. America has now her Henry, and is satisfied. Mr Preece.

The following is the official report of the resolutions arrived at:—

"*Resolved*,—That the several Governments represented by the "delegates of this International Congress of Electricians be, and "they are hereby, recommended to formally adopt as legal units "of electrical measure the following:—As a unit of resistance, "the *international ohm*, which is based upon the ohm equal "to 10^9 units of resistance of the C.G.S. system of electro-"magnetic units, and is represented by the resistance offered to "an unvarying electric current by a column of mercury at the "temperature of melting ice 14·4521 grammes in mass, of a con-"stant cross-sectional area, and of the length of 106·3 centimetres.

"As a unit of current, the *international ampere*, which is "one-tenth of the unit of current of the C.G.S. system of "electro-magnetic units, and which is represented sufficiently "well for practical use by the unvarying current which, when "passed through a solution of nitrate of silver in water, and in "accordance with accompanying specifications, deposits silver at "the rate of 0·001118 of a gramme per second.

"As a unit of electro-motive force, the *international volt*, "which is the electro-motive force that, steadily applied to a "conductor whose resistance is one international ohm, will "produce a current of one international ampere, and which is "represented sufficiently well for practical use by $\frac{1,000}{1,434}$ of the "electro-motive force between the poles or electrodes of the "voltaic cell known as Clark's cell, at a temperature of 15° C., "and prepared in the manner described in the accompanying "specification.

Mr. Preece. "As a unit of quantity, the *international coulomb*, which is "the quantity of electricity transferred by a current of one "international ampere in one second.

"As a unit of capacity, the *international farad*, which is "the capacity of a condenser charged to a potential of one "international volt by one international coulomb of electricity.

"As a unit of work, the *joule*, which is equal to 10^7 units "of work in the C.G.S. system, and which is represented "sufficiently well for practical use by the energy expended in "one second by an international ampere in an international "ohm.

"As a unit of power, the *watt*, which is equal to 10^7 units "of power in the C.G.S. system, and which is represented "sufficiently well for practical use by the work done at the rate "of one joule per second.

"As the unit of induction, the *henry*, which is the induction "in a circuit when the electro-motive force induced in this "circuit is one international volt, while the inducing current "varies at the rate of one ampere per second.

"The Chamber also voted that it was not wise to adopt or "recommend a standard of light at the present time."

An attempt was made to introduce other units, but the feeling is pretty strong that language-framing electricians must rest on their oars for a time. New ideas and new measurements must have new terms and new names, but the general public must become more accustomed to the new language already invented before proceeding to manufacture more novelties in phraseology. The new terms are even now very difficult to explain, and still more difficult to understand. Moreover, electricians themselves are not sufficiently unanimous either as to the necessity or upon the accuracy of the definitions of the new conditions, and therefore they can afford to wait for a final settlement for another congress some years hence—perhaps in Paris in 1900.

IV.—The Exhibition.

Nothing grander in design or more beautiful in execution has ever been seen in this world than the group of buildings situated in

Jackson Park, Chicago, and called the "World's Fair." It is a great misfortune that the world did not appreciate, nor respond to, the ambitious views of the conveners of this fair. Their conception was magnificent. Their architects, if they did not originate the plans, certainly rose to the occasion. Their builders realised their views. Every possible convenience and accommodation was provided for exhibitors, but the response was poor; and the internal management of the whole business, owing to inexperience and perhaps overweening confidence, was indifferent. The success of the undertaking hovered for some time over failure; but fine weather, patriotism, novelty, real beauty, and cheap fares at last attracted crowds, which, numbering about 200,000 a day, have converted what looked like a disaster into a well-deserved success. I have not much to say of the Exhibition as an exhibition. It was very like its predecessors. It did not attract me; for, having taken part in nearly every exhibition for the last 15 years, I am sick of exhibitions. I devoted much attention to the electricity building, and observed there several novelties, some of which I have referred to in other parts of this report. Mr. Preece.

Gray's telautograph attracted much attention. It is an improvement on Cowper's writing telegraph. It reproduces the motion of a pen, so that while you are writing in London a phantom hand seems to guide the pen and reproduce your own writing in Nottingham. You can see the pen move, dot the i's, and cross the t's. It makes corrections and erasures. It works well, but very weirdly. My writing and signature were clearly reproduced at the very first trial. But it is immature for practical trial at present. It has not reached its final stage. It is being improved every day. It is very complicated in construction, and it requires four wires to work it. The Western Union Company in Chicago have established a circuit between their head office and stores department, and are giving it a good test.

The French and German Administrations sent admirable and extensive displays of their historical and working apparatus, with a very large staff of men to attend to them, but I am pleased to say that our Post Office exhibit proved much more attractive and interesting. It was better arranged and more complete; and our

Mr. Preece. one solitary assistant, Mr. J. Chapman, won golden opinions by the admirable way in which he attended to his duties, and by the excellent verbal explanations he gave of our show.

The United States of America made no historic exhibit, but the Western Union Company showed many relics and examples of Morse's early work.

The American public were surprised to find how much we in England had anticipated their work. Morse's first message, "What has God wrought?" was sent only in 1844. Our history commenced in 1837. Our jubilee was celebrated in 1887. Theirs is to be celebrated this year.

An exhibit that attracted much attention was a door which opened before you as you approached it, and closed behind you as you receded from it. This was done by a small electric motor which was set in motion when you stepped on a mat, and released when you passed through the door. It was worked with the same current that would light a glow lamp.

Both on entering the harbour of New York, and on going by steamer from Chicago to the World's Fair, channels for the passage of the steamship were clearly marked out at night by glow lamps fixed on spar buoys, and lighted up in series.

There was shown an electric selector of great merit and some originality. It was a plan by which any particular railway station could be selected and called, any particular signal cleared or put to danger, any office on a long circuit with several intermediate instruments selected and secured, any subscriber on a combination telephone circuit—that is, on a single circuit upon which several renters are fixed—could be called and isolated from the rest.

All the great manufacturers in the United States made large exhibits of their wares. The American Bell Telephone Company, the Western Electric Manufacturing Company, the General Electric Company, the Westinghouse Company, the Standard Electric Company, had splendid shows, but few novelties. Their novelties have already been referred to, either under electric lighting or electric railways.

Electric lifts were on exhibition, and in use. They worked

very well indeed, and are rapidly coming into general use in the States. The New Postal Telegraph Building in New York is being fitted with several of these lifts, which are going to be worked very quickly indeed (600 feet a minute). They are being installed by the Sprague Company. Mr. Preece.

Electric welding was shown in full operation, and attracted much attention.

Power was transmitted all over the place by currents, and whole exhibits were shown in motion by means of electric motors.

Along the Machinery Hall, 1,400 feet in length, an electric crane, 75 feet span, travelled, and formed an admirable point of observation for those who were allowed to travel on it. It was used in the preparation of the Exhibition to lift and fix all the machinery. It lifts and moves 40 tons. It is worked by five motors. Its weight is 58 tons, and its speed was excellent.

There were large exhibits of every class of cable manufactured in the States—Waring, okonite, kerite, Patterson, dry-core, &c.; and Felten & Guilleaume had in the German section a fine show of their own make. Sections of streets were shown, with pavement, manhole, conduits, joints, and everything complete.

England is the home of the alternator, but it has now taken firm root in America. In 1884 there was not a single one to be found in Philadelphia. Now they are everywhere, and alternate currents are being studied and developed in a way that is completely putting our experimentalists in the back row.

The paucity of real novelties, or of what are commonly known as "Yankee notions," was very marked. The necessity for such things—that is, the scarcity of labour—has apparently disappeared, and with its parent the child has languished. Moore's spark-interrupter—an automatic vibrating armature in a vacuum tube, by which glow lamps can be turned up or down without wasting energy—was described at a meeting of the electrical engineers at New York, but I did not see it at the World's Fair.

The distinguishing feature of the Chicago World's Fair was not alone its uniqueness, but its grandeur and its magnificence. It was not an exhibition of goods and manufactures in the old-

Mr. Preece. world sense. No one seemed to care two straws for the mere trade exhibition *per se;* he admired the beautiful buildings, the water-ways, the external attractions, and, above all, the congeries of people that assembled from all quarters of that great continent in such multitudes.

The distinguishing feature of American engineering is the great scale on which it is carried out, and the rapidity of its adoption. An electric railway from Chicago to St. Louis, 250 miles long, is not a difficult engineering feat, for the country is level, but it is novel for the fact that it is projected to travel at the rate of 100 miles an hour.

There were some things in the Exhibition that were extremely interesting. The first was a complete reproduction of an ancient Viking's war-ship—an open boat, that would excite fear and trembling even in crossing the Channel, but of a type that probably crossed the Atlantic long before the famous fleet of Columbus. These vessels—the "Santa Maria," "Pinta," and "Nina"—were also reproduced in all their dimensions, and in all their colours and fittings. The contrast between these relics of the past and the modern war-ship built alongside the home of the British Commission, Victoria House, was, to my mind, more suggestive than all the innumerable wares and appliances so freely exposed in the vast extent of covered area.

One interesting building was a kind of baby cloak room, where mothers could book their babies for the day, and who were there carefully tended, nursed, amused, and fed for a very small charge. Each mother received a small brass check, which was her guarantee for the safe custody of her little beauty.

V.—Electric Lighting.

Electric lighting has not generally made the rapid progress during the past nine years in the States that was expected from its great rate of growth during the previous four years. Wild speculation, hasty construction, fatal accidents, and frequent failures have reacted on steady progress. At the same time the advance has been very great, principally in public street lighting. All towns and villages in all parts of the country, however small

and isolated, or however distant, seem to have adopted public arc lighting. Arc lamps are found suspended over the roadways in a very rough-and-ready way, sometimes from stretched wires, sometimes from long balanced levers, but always effective. Mr. Preece.

The arc lamp-posts are generally of timber, like telegraph poles; occasionally squared timber, as in Broadway, New York; and sometimes plain and neat iron poles, made of differing sections of iron pipes, but rarely so heavy, massive, artistic, and expensive, as in England. Clear glass globes appear to be almost universal in use. It is quite rare to see frosted glass or opaline shades.

The principal novelty introduced has been the use of flat carbons of oval or elliptic section, to increase the duration of the light. They are 310 millimetres long; the major axis is 25 millimetres, and the minor 11 millimetres. The ordinary arc lamp burns as a rule only eight hours, but this flat carbon doubles its life. Moreover, the flat carbon is found very advantageous and useful with alternating-current systems, on which arc lamps as a rule work badly. The standard current used is 10 amperes, and the energy expended varies from 400 to 500 watts. The lamps burn very steadily as a rule, and give a light of about 800 candles at the angle of maximum intensity.

An excellent self-regulating alternator for public arc lighting, designed by Stanley, was exhibited by the Westinghouse Company. It maintained its current quite constant, however much the number of the lamps was varied, between 0 and 24. Any number could be turned on or off without the least difference being detected in the current on the light.

The favourite arc dynamo in the States is said to be that supplied by the Standard Electric Light Company. There was a large exhibit—six machines—of this type in the Exhibition. The largest size worked with 6,550 volts, and maintained 120 arcs in series. It is fitted with a very effective and rapid working automatic governor, regulating the range of the brushes, so that as lamps were turned off the current was maintained constant and the voltage changed. Six seconds only were needed to regulate the brushes from a load of one lamp to 50 lamps.

Mr. Preece. Arc lighting is used very much for shop-lighting, not only in the interior for general illumination, but for advertising and attractive purposes outside. Indeed, many of the streets of the principal cities—especially New York and Chicago—are more brilliantly lighted by the shopkeepers than by the municipalities. In fact, in many cities there are many more arcs supplied for private than for public purposes.

Incandescent Lighting.

Glow lamps are, within my observation, invariably used in telegraph offices, post offices, telephone exchange rooms, hotels, and in many railway stations.

The electric light is more general in such public places than with us. I did not visit a single place that was not so fitted, and with glow lamps. In private houses it is much used, but not so generally as with us. In Chicago the residential lighting is only 33 per cent. of the total. In all large cities there are immense blocks of buildings fitted with lifts and used as offices. In all cases they were lighted by their own isolated plants. One of the most striking features of a bird's-eye view from some lofty spot of a great city, like New York or Chicago, is the white, fleecy, wool-like jets of vapour that float gracefully away from the top of every large building. They are to be reckoned by the hundred, and every one means steam plant working lifts and electric light. The Western Union Company at New York and Chicago have their own steam plants.

When I visited Chicago in 1884 no central electric lighting station had been built, and no current was supplied. Now, a capital of $2,233,000 earns an income of $320,000 yearly.

The glow lamps (16-C.P.) fixed are	136,409
Arc lamps fixed...	4,376
Motors supplied—total H.P.	3,612

and this is equivalent to 430,000 10-C.P. lamps fixed, or such lamps as we reckon with in England.

The maximum load is 50 per cent. of these lamps alight at one time, which accords with our experience in England.

The price works out at 7½d. per kilowatt-hour, or supply unit,

and this includes the cost of the renewal of the lamp. The cost of production works out at 3½d. per unit. The cost of the production of electric energy in the States differs, therefore, very little from that experienced here. It is everywhere steadily on the decrease. As the load increases, as the daily supply lengthens in duration, as the generators increase in size, so will the cost diminish; and how low it will fall no one can predicate. Anyway, it will certainly far exceed in economy the production of gas. Mr. Preece.

The price of lamps to the undertaker—that is, to the electric light company—is 1s. 4d.; the life of the lamp is 600 hours. A 16-C.P. lamp takes 0·45 amperes and 110 volts. It is, therefore, a 50-watt lamp, and a better one than we get at present in England. The screw socket appears to be in universal use. I wish it were so here.

There are three central stations in Chicago. A new station is being built alongside the water in Harrison Street with a capacity for utilising 20,000 H.P., where every modern appliance for cheap fuel, automatic feeding, condensing, and economising will be used.

The south side central station is worked by natural gas, which is brought in pipes 100 miles long from Indiana. It is very cheap compared with coal.

I found in use in Chicago a system of raising the voltage on the feeders when the pressure falls, owing to the increase of load, by switching in motor dynamos. They have given the name of "boosters" to these instruments. A somewhat similar system has been applied at home at the Midland Railway, Derby.

The Exhibition and its surroundings were, of course, brilliantly and entirely lighted by electricity.

The accumulator in America has been a failure for electric lighting, and a very strong prejudice exists against its use. It has led to much litigation, and the best forms seem little known there. The lagoons of the World's Fair grounds were, however, very successfully navigated by extremely pretty electric launches, worked and lighted by accumulators. The grounds at night, brilliantly illuminated and interlaced by winding waterways, with wooded islands and pretty bridges, along which illuminated

Mr. Preece. gondolas and silent launches floated noiselessly, formed most beautiful and fairy-like scenes, superior to anything seen in Venice or pictured by art.

The feature that distinguishes American from English engineering practice is the persistent use of belting and countershafting. In some stations the belting was to English eyes appalling. Direct driving is only now making its way. There were several direct-driven engines and dynamos exhibited in the American section at the World's Fair, and some new stations now being built are to be direct-driven. The Willans & Robinson engines on show at the Exhibition, and a steam turbine exhibited in the Swedish section by Laval—a form somewhat similar to that of the Hon. Charles Parsons, who unfortunately did not exhibit—attracted much attention. The reports of our performances in England are much sought after, and I think one influence of the Chicago gathering will be to convert American engineers to direct driving.

The elastic character of direct-driving engines, gradually increasing in number and capacity with the load, and the ability to shut down or turn on engine after engine as the load varies, are economical advantages of immense value. The rapid regulation of small engines, the much smaller space occupied where space is so valuable, the smaller capital expenditure involved, and the reduced working expenses, all give direct driving an advantage which should recommend itself to such eminently practical engineers as the Americans.

The General Electric Company showed in the World's Fair a 1,000 H.P. triple-expansion vertical marine type engine, driving two 400-kilowatt multipolar dynamos, and the Chicago Edison Electric Light Company are fitting up their new central station with such direct-driving engines.

No one would continue to make huge dynamos, with a speed of 90 revolutions per minute, when convinced that smaller instruments of the same power may be run with equal economy and success at 350 revolutions per minute.

The town work at such places as New York, Boston, and Chicago is as solid and substantial as anything we can show in England; but when we inspect the outlying works in country

towns, we can only express our thanks that we have the control of the Board of Trade and the protection of an Act of Parliament. It is the fashion to decry grandmotherly government, and to wince at departmental espionage; but the protection of life on our railways, the absence of accident in our electric light undertakings, and the solid character of the work done everywhere, as compared with the same conditions in the States, can lead to but one conclusion—viz., that, if we are slower, we do these things at least better in England. Mr. Preece.

It is all very well in the pioneer stage of any industry to let private enterprise have its full swing, but when an industry becomes a public necessity, and when the interests of the whole community are at stake, Government, as the custodians of the public weal, must step in and assume the control. The accidents in the States are terrible in their number and fatality; and they strike the observant Englishman with dismay. The value of life there seems to be very much below par.

VI.—Electric Railways.

The progress made in the establishment of electric railways is the most wonderful instance of growth of electric industry observable in the States. In 1884 I found only one railway so worked, and that experimentally, at Cleveland. Now every town has its electric railway. There are 4,000 miles of line so worked, 6,900 motor cars, and 4,000 trailing cars.* The capital embarked is $13,000,000, and the rate of progress is scarcely checked by the serious financial depression that has passed over the country.

Electrical appliances of all kinds for railway working were among the most conspicuous exhibits at the World's Fair. A special track was laid down for test and trial, and along here I inspected a 30-ton locomotive, the heaviest yet made, having a horizontal pull on the level of 6,000 lbs., or enough to draw 500 tons on an ordinary English railway.

The type of railway in general use over the United States of America is very uniform. We have only one true example in

* Trailing cars are not fitted with motors. They carry passengers only, and are drawn by motor cars.

Mr. Preece. England, and that is at Leeds. A modification of the system has, however, been adopted on the South Staffordshire Tramways, and is about to be introduced in Coventry. The wires are all overhead. A heavy insulated copper wire is suspended over the centre of each pair of rails, or "track," and called the "trolley" wire. This conveys the current from the power house. It is picked up by a trolley rod, which presses, by the action of a spring, upon this wire, and so conveys the current to the motors, which are geared to each of the two wheel shafts of the car. The current is thence transmitted through the wheels to the rails, and it returns thence to the power house by heavy copper returns buried in the ground or suspended on the poles.

There were two very fine specimens of electric railways in Chicago. One, the intra-mural railway, conveyed visitors to and from different parts of the grounds of the World's Fair, working very well, carrying an immense number of people, and was financially very successful. It was not a trolley line, but it had a third rail acting as the main conductor. The other is the Chicago North Shore Street Railway, running to Evanstown. This is a trolley line having iron poles of strong design and good taste. It is 7½ miles long, with a power house situated in the middle of the line. It has 16 motor cars and 16 trailers. The feeders are carried on wooden poles, which are very unsightly. These feeders could have been more economically and more efficiently put underground.

In the power house they are using a simple horizontal reciprocating engine, driving a Thomson four-pole dynamo, fitted with carbon brushes, by means of continuous rope gearing. No sparking whatever is observed at the brushes, and nothing can work more smoothly; but the absence of condensing and the existence of rope gearing must render the engine part uneconomical.

The maximum H.P. used is 246. The voltage varies with the load from 500 to 550. The current averages 200 amperes.

The maximum number of cars on at one time is nine motors and nine trailers, and this averages at the power station 13·7 H.P.

per car running. The cars run on the straight at from 16 to 20 miles an hour. The rails are 85 lbs. per yard—a very heavy rail for a tramway. The usual rail is 52 lbs. per yard, as at Boston; but experience in the United States of America is leading to heavy rails. The pounding and hammering on the rails with heavy loads is very great, and in Philadelphia they are using even 90-lb. rails. Mr. Preece.

The trolley wire alone is not unsightly, but when it is protected with three guard wires, as at Boston, and the same poles carry the feeders, it becomes hideous, and it is astonishing that the American community submit to it. Such a system is impossible in England.

This trolley wire must be elastic, otherwise the trolley itself frequently jumps off and stops the car. Attempts have been made to improve the appearance of the road by using handsome central iron poles, with solid brackets on each side to carry the two trolley wires, but the want of elasticity has introduced fresh evils. The trolley frequently comes off, and great sparking is evident.

An admirable illustration of a modern electric railway is the electric *portage* between Lakes Ontario and Erie, from Chippewa to Queenstown, 13 miles long. It is on Canadian soil, and built with Canadian capital, but the work was done by an American firm. It is an open overhead trolley line, with iron posts and brackets. It is worked by water power derived from the Niagara Falls.

The West End railway system of Boston is by far the most extensive electric railway system in any city in the States.

In the power station, which is situated on the harbour, there are 24 Babcock-Wilcox water tube boilers, each developing 250 H.P.

Surface condensing is used, sea water being available for the purpose.

There are six horizontal triple expansion engines, each developing 1,000 H.P., and driving by means of belting 18 Thomson-Houston four-pole dynamos, all capable of being connected up in parallel, but put on and off as the load varies.

The chimney is 252 feet high and 13 feet 6 inches in diameter.

Mr. Preece. It does not smoke, and the steam is generated so economically that only 11½ lbs. are used for one H.P.-hour.

There are three power houses in Boston, the other two developing 2,000 H.P. each, so that there are 10,000 H P. used in Boston for working their street railway system.

The line is no longer run by contractors. It is entirely in the hands of the railway company itself. They have magnificent workshops, and a very fine staff. Their chief engineer, Mr. Hirt, was extremely attentive and communicative. He supplied me with capital drawings of the works and general arrangements.

The use of belting was again surprising; but I was told that a very large railway system at Brooklyn was going to be worked by direct-driven power, so as to obtain an authoritative and convincing trial of the relative merits of the two systems. I did not learn the type of engine to be fixed at Brooklyn, and I was unable to go there to find out.

The track is light, as I have previously mentioned, but they are welding together the fish-plates and the rails so as to obtain an electrically perfect return circuit. I saw the car and apparatus used for this welding process, but I could not see it in operation, for one essential part of the plant was being repaired.

I saw the electric snow ploughs used to keep the tracks clear in wintry weather.

The system of railway working in Boston has given such satisfaction to the public that the traffic returns have improved 30 per cent. owing to the change from horses to electricity. The service is so much quicker, cleaner, and better performed. A railway car in full service is said to run an average distance of 250 miles a day, and its mean speed is 15 miles an hour.

There is an important question under discussion in the United States of America—whether it is better to pursue the present practice of using two motors upon the cars, one on each wheel axle, or to use only one motor connected electrically and flexibly with the wheels by bevelled gearing. This is the plan advocated and practically carried out by Mr. Sperry. The weight is thus placed in the middle. The horizontal pull is said to be greater. The

starting torque is smaller. It is more easily controlled. There is no slip, and the velocity of all parts is uniform. It will climb a stiffer grade. One 35-H.P. motor replaces two 30-H.P. single-reduction Thomson-Houston or Westinghouse motors with economy of energy. The system is working in Pittsburg, where it was adopted after a very severe trial with a Westinghouse car, and it is about to be used on 22nd Street in Chicago. It has this disadvantage—that if the motor fails there is not a second one available to take the car home. The problem is an interesting one, and its solution will be watched with great interest, for it has an important bearing on the economies of our English roads. Mr. Preece.

The feeling is pretty prevalent in the States that the conductors must eventually go underground. Experiments in this direction are being made in several directions, notably in Washington and Chicago. The trolley with its guard wires is really an abomination, and the disturbances created by insufficient return accommodation are annoying the telegraph and telephone interests, and alarming the gas and water companies. The future working must be metallic circuits and underground conduits. It is so done in Buda-Pesth, and it has been partially done in Blackpool and in Rome. Other experiments are contemplated in England. No one can doubt that the future of electric railways is very bright. The South London Railway and the Mersey Dock Elevated Railways are examples of great successes in England, but it is in the States, where this form of locomotion has become a necessity, that we are sure to see a speedy and practical solution of the problem.

CONCLUSION.

I have by no means exhausted the many notes made during my trip, but I have said enough. Interviewing is a feature of American journalism that, thank goodness, has not taken root here. I was surprised to read of interviews with myself, extending to two or three columns, that resulted from the passage of a few compliments; but I was more surprised to find that statements supposed to have been made by me to an interviewer were taken *en serieux*. One irate functionary compared an official statement

Mr. Preece. of a past Postmaster-General with a mythical statement made by me, and triumphantly pointed out such a glaring contradiction as a complete refutation of my fallacies. I even read that I had stated that we electricians in England had *nothing* to learn from America. I have no recollection of ever having made any remark which could by any shorthand blundering have been construed into such an absurdity; but if I had done so it would more likely have been one where "nothing" was a telegraphic error for "everything."

I cannot too gratefully speak of the attention and kindness I received from everyone, and I certainly feel that I have personally profited from my visit very much indeed.

A visit to the United States is something like charging an accumulator. It stores the visitor with energy. When I am completely discharged, and my adverse criticisms have been forgotten, I shall probably cross the Atlantic again.

The President. The PRESIDENT: We are fortunate in having some American friends among us this evening, who may like to make a few remarks on Mr. Preece's admirable paper, and I am sure you will like to hear what they have to say on the subject. I believe Mr. Keith, of Chicago, is present.

Mr. Keith. Dr. N. S. KEITH: Mr. President and gentlemen,—Your worthy President has made something of a mistake in introducing me as from Chicago. I hail from San Francisco—still further away from this country. I made an extended visit at the Fair; I attended the Electrical Congress as well, and made special observations of the electrical exhibition at that place. I agree perfectly with the remarks of Mr. Preece, so far as they went in relation to the Exhibition electrically. I wish to add this, however—that a great deal of the success of the Exhibition rested upon the electrical department. Its power features were essentially electrical. Of the 30,000 H.P. of engines and boilers provided for the power purposes in the Machinery Hall and its annexe, 27,000 H.P. was devoted to the production of electricity for various purposes. That 27,000 H.P. was divided for the purposes of light, and for the purposes of transmission and distribution of power over the entire Exhibition. Under the

Dr. Keith.

rules of the Exhibition no fires were allowed in any of the buildings, except in the annexe to the Machinery Hall, where the boilers were located. There were no other methods of conveying power or of generating power in any of the buildings than that which proceeded from Machinery Hall by means of electricity. There the electricity was generated, and was distributed by underground wires in large conduits, through which men might pass upright, and carried to all the buildings where power was desired. In the Mining Building there were two large motors of 150 H.P. each. These supplied the power that was necessary for the exhibition of the mine machinery. In the Electricity Building no electricity was generated, except in a secondary or tertiary or quaternary manner. The power was generated in Machinery Hall, transmitted by electricity, and reproduced by electro-motors. It was applied then again to dynamos, and from dynamos even again to electro-motors, for the purpose of showing the capacities of various apparatus. The lighting of the grounds was such that it attracted many visitors by night. That lighting has been spoken of by Mr. Preece in a very vivid manner. There were something like 100,000 glow lamps—or incandescent lamps, as we call them—and 2,500 arc lamps scattered over the grounds for lighting externally. That was independent of the arc lamps and glow lamps exhibited by exhibitors in the Electricity Building. The Electricity Building was illuminated every night. The other buildings were illuminated once or twice per week, moving from one building to another, the Mining Building and Manufactures Building, and the Agricultural and various other buildings, having their evenings once or twice a week. There was a strange incongruity in the use of the electric lamps. There was an annexe to the Exhibition called the "Mid-Way Plaisance." In that Mid-Way Plaisance, on either side of a large street some three-quarters of a mile in length, were exhibitions of different nationalities. There were Samoans in the Samoan village, Javanese in a Javanese village, Chinese in a Chinese village, Irish in an Irish village, &c., &c. There were two Irish villages. There was the village gathered round Blarney Castle, in which they exhibited the Blarney Stone; but

Dr. Keith. when it was found that the Blarney Stone had not been moved to Chicago, they said it was a stone from Blarney, which was all the same thing. In these huts of Hottentots and Samoans, Chinese, Japanese, Turks, and Javanese, and in the Cairo street, were incandescent lamps and arc lamps. In the cottages—where, naturally, they hardly could support a rush lamp—you saw the strange incongruity of a hanging incandescent lamp to light the building. It was a very notable feature to those who notice such things; but I suppose the average visitor only went to see the show, and that to him the incandescent lamp was not a part of it; but at the same time these exhibitions would not have been so successful if they could not have been lighted in the more modern and civilised way. Incandescent lighting was a very pretty exhibit in the illumination of the Ferris Wheel, some 250 feet in diameter, the topmost part being 264 feet from the ground. The circles of this wheel were illuminated by incandescent lamps, and the spokes, and parts in the towers which supported the wheel. At night it was a very pretty sight. There were some 2,000 incandescent lamps used for the purpose of illuminating the wheel. They had a separate or isolated plant from that used for illuminating the mass of the Exhibition itself. I am sorry that time is so limited, it being so much past your usual hour of adjournment; because, so far as the Exhibition is concerned, I am full of it, and could tell a great deal. I wish, however, to make one remark, which is perhaps a little self-laudatory, with regard to the telegraphs. It struck me as Mr. Preece was speaking of the telegraphs. In San Francisco—where I have been manufacturing electrical apparatus, dynamos, motors, and so forth—the Postal Telegraph Company, as an experiment, put in a motor dynamo, run from the incandescent lighting circuit of the city, and from the dynamo draw various differences in potential, or electro-motive forces, for the working of their several lines—some 50 to 60 different lines, and several different electro-motive forces, from 350 volts positive and negative, making a total difference, if need be, of 700 volts, for working their quadruplex system, down to 45 volts, for working their short lines—from the one commutator and the one dynamo without

sparking; and up to the time I last heard—some two months ago—it had then been working six months, with a great deal of success. We made for them two motor dynamos, so that if one gets out of order the lines can be immediately thrown to the other, for safety; but they have had no accident so far. I should be pleased to give the particulars of the construction to anyone who may desire them. Dr. Keith.

The PRESIDENT: Gentlemen,—I think our best thanks are due to Mr. Preece for having brought his trip to such a very advantageous conclusion for this Institution that we have been able to accompany him—or, I ought to say, you have been able to accompany him in spirit on his trip, as I had the privilege of doing in body. At this late hour I will not enter upon any detail, but simply ask you to pass a hearty vote of thanks to Mr. Preece. The President.

The resolution was carried by acclamation.

The PRESIDENT: I have to report that the scrutineers declare the following candidates to have been duly elected :—

Foreign Members :

Oscar Bihet.	Samuel G. Neiler.

Richard Henry Pierce.

Associates :

Henry John Andrews.	Charles Lewis French.
Philip Francis Anstruther.	John Grant.
Frank Ayton.	C. J. Whistler Hanson.
H. Brookes-Edwards.	W. Marshall Huskisson.
Cox Pearson Chambers.	William John Kelly.
William Challoner.	John William Leyshon.
George Granville Clarke.	Alfred Marshall.
William Henry Eaves.	Alfred Ernest Le Rossignol.
Augustus Eckstein.	Thomas William Skinner.
Michael Birt Field.	Frank H. Starling.

Students:

Gerald Carlyle Allingham.
Frank Armstrong.
Walter James Belsey.
James Herbert Edwards.
William R. Elliott.
Louis Henry Euler.
William Fennell.
Herbert Francis Hunt.
Lionel C. Johnson.
Albert Henry Joyner.
Philip E. Lewis.
W. M. Nelson.
William Samuel Parsons.
Eliot Charles Pringle.
John Thomas Redmayne.
Charles Alfred Spon.
Frederick William, Baron de Tuyll.

The meeting then adjourned.

ABSTRACTS.

S. J. LOCHNER—ON THE ELONGATION PRODUCED IN SOFT IRON BY MAGNETISM.

(*Philosophical Magazine, Vol.* 36, *No.* 223, *p.* 498.)

The author used for his researches an instrument resembling in its essential features a Michelson interferential refractometer, of great sensibility, the elongation being measured by means of a mirror, and the limit of sensibility being lower than one-millionth of an inch. He found that the route by which a certain magnetising force had been arrived at affected the amount of expansion for that force, the expansion varying for rising and falling currents in a curve very similar in shape to the hysteresis cycle.

His general results may be summed up as follows:—They indicate that the expansion is a function of the ratio between the diameter and the length, and that the elongation varies directly as, possibly, the square root of this ratio. Also, that the expansion varies directly as the permeability. That the amount of magnetising force required to produce the maximum expansion, and the point of no expansion, depends on the ratio between the diameter and the length. That there are two maxima—one produced by increasing the current, and another by decreasing the current from the point which produced the first maximum. That the first contact gives more expansion than the second and following contacts; and, further, that hese appear to disagree among themselves, the expansion falling off with subsequent contacts. The paper is fully illustrated with tables and diagrams.

R. HENNIG—THE PERMEABILITY OF OXYGEN.

(*Wiedemann's Annalen, Vol.* 50, *No.* 11, *p.* 485.)

This is an account of a new determination of the relative permeability of oxygen and atmospheric air by Toepler's method, the principle of which is as follows:—A glass tube of small internal diameter has a slight bend in it, and is placed symmetrically in a magnetic field, the bend being downwards and filled with a short thread of some liquid, the arms on either side being filled with the gases whose permeability is to be compared. If one gas is more permeable than the other, it is attracted with greater force into the magnetic field, and this action is balanced by the force of gravity against which the thread of liquid has to be raised. Any want of uniformity in the field can be detected by filling both limbs with the same gas and observing the deflection, and formulæ are worked out for the difference in permeability, with this correction. Methods of measurement of the field are discussed, and Weber's bifilar method is preferred, owing to the small size of the requisite apparatus and the long range of the values which may be accurately determined. The mean error of the author's observations is about 3½ per cent., and the probable error is 1 per cent.

The following table gives the author's result, compared with other observers':—

Observer.	Temperature.	Pressure. Atm.	$(\mu_1 - \mu_2) \times 10^6$, reduced to 1 Atm.
Quincke ...	16°	1–8	0·097
		40	0·125
Du Bois ...	15°	1	0·093
Curie	20°	5–20	0·121
Hennig... ...	25°	1–4	0·096

B. SZAPIRO—THE USE OF VOLTMETERS IN ALTERNATE-CURRENT STATIONS.

(*Elektrotechnische Zeitschrift*, *No.* 32, 1893, *p.* 466.)

The author remarks on a small correction necessary in voltmeters containing iron when used with alternating currents. He points out that the reading of the voltmeter depends, not merely on the frequency, but also on the shape of the alternate pressure wave. He starts with the general equation,

$$E^1 = E_1 \sin m t + E_3 \sin (3 m t + a) + E_5 \sin (5 m t + \beta) + \ldots,$$

representing any curve which is symmetrical as regards the axis of abscissæ, and works out values for the effective current; from which he draws the general conclusion that in a certain circuit of given resistance and self-induction the strength of current for a given effective pressure varies with the shape of the pressure curve. In particular, where the self-induction is relatively small the strength of current is independent of the pressure curve; when the curve is nearly a sine function, and the resistance of the circuit comparatively large, no very great difference occurs in the value of current with different E.M.F. curves.

But if the resistance and self-induction are of the same order of magnitude, the differences in current-strength may be very noticeable. And in taking the particular case of a Ganz machine the author finds for a voltmeter of resistance 1,000 and coefficient of self induction = 1 that the error is about 8 per cent. The author therefore advises that all iron instruments should be calibrated on the alternator for use with which they are designed.

Lord KELVIN—ON A PIEZO-ELECTRIC PILE.

(*Philosophical Magazine*, *Vol.* 36, *No.* 221, *p.* 342.)

This is a description of an apparatus constructed by the author, briefly as follows:—Twenty-four double plates of zinc and copper soldered together are taken, and the corners of the zinc plates cut off, in such a manner that one side of the plate is a square of 8 centimetres of copper, and the other a similar sheet of zinc, but with the corners removed and showing the copper. These plates are piled together with distance pieces in such a manner that an air space of 3 or 4 mm. is formed between

the zinc of one and the copper of the next. Connect the bottom and top plates to the quadrants of an electrometer, and discharge all parts of the apparatus; and then let a weight of a few pounds fall from an inch or so on to the top plate and rest there. A startlingly great deflection is produced, and if the zinc is at the top it becomes positively charged. A similar instrument was invented by Messrs. J. & P. Curie, and described in 1881.

J. TROWBRIDGE—ON THE OSCILLATIONS OF LIGHTNING DISCHARGES AND OF THE AURORA BOREALIS.

(*Philosophical Magazine, Vol.* 36, *No.* 221, *p.* 343.)

When air is subjected to a sudden strain due to an electrical discharge, it acts like an elastic solid, and cracks in zigzag fissures, and through the crack thus produced by the first oscillation the subsequent ones take place. The author has made some new photographs of sparks by the rotating mirror method, using an alternator and a step-up oil transformer and a Ruhmkorff coil; an idea of the power employed being given by the fact that when the sparks were passed through the secondary of a transformer (turns not given), the primary circuit of two layers of thick wire lighted three 50-volt Edison lamps in parallel. The photographs are given, and are exceedingly interesting. From 10 to 12 oscillations can be traced, about three in the same path, the time interval being about one hundred-thousandth of a second. For three hundred-thousandths of a second, therefore, the air remains passive, and the heat is not conducted away.

With reference to the question of lightning, the author refers to its inductive effects on electric circuits: he notes that lamps often "blink," and sometimes go out, when a lightning flash takes place in the neighbourhood. He considers it dangerous to put electric supply wires on gas fittings for this reason, and has known a gas leak to be thus ignited.

The photographs show that after a few oscillations the discharge ceases to be disruptive, and becomes a brush glow—as in the case of a vacuum tube; and the author considered the latter case to be allied to Aurora Borealis. He therefore experimented with stratified discharges, and found that period of oscillation had no effect on the distance of the stratifications apart. Self-induction also has no effect, but resistance has. On the other hand, transitory stratification can be produced by applying the finger or other earth connection to a vacuum tube. The author therefore considers that the waving of the Aurora Borealis is due to intermittent or moving earth connections due to damp air or cloud. He sees no reason to believe in the rapid oscillation of the Aurora.

J. SAHULKA—EXPLANATION OF THE FERRANTI PHENOMENON.

(*Elektrotechnische Zeitschrift*, 1893, *No.* 52, *p.* 739.)

One of the most remarkable of the so-called Ferranti effects is the rise in the ratio of transformation of a transformer whose primary is coupled to an

alternator, and whose secondary is connected to a condenser of capacity not exceeding a certain value; under which circumstances the primary volts rise, and the primary current falls.

The author shows in the first instance, from theoretical considerations, that the explanation of the phenomenon is caused by so-called "drop," or leakage of magnetic induction, and proceeds to describe some experiments bearing out his theory.

Supposing L_1 and L_2 the coefficients of self-induction of the two circuits, and M their mutual induction, and if N_1 and N_2 are the respective number of turns, then, if there be no magnetic leakage, $M^2 = L_1 L_2$, and the transformation ratio is $V = N_2 : N_1$; but if there is leakage, then M^2 is less than $L_1 L_2$, and V is less than $N_2 : N_1$, or, as is well known, the ratio of transformation is reduced. Now, if the secondary be coupled to a condenser of capacity C, L_2 becomes $L_2 - \frac{1}{(2\pi n)^2 C}$, where n is the frequency; and in this case, where there is magnetic leakage V becomes greater than $N_2 : N_1$—that is to say, the transformation ratio is raised, and depends on the capacity of the condenser. The apparent resistance of the primary, and the primary volts of the transformer are raised, while the primary current falls.

In the remaining part of the paper are described experiments made with a transformer having a cylindrical core made of iron wires, and wound with four layers of 73 turns on one quarter of its length, and on the remaining three-quarters with four layers of 219 turns. If these be used as primary and secondary respectively, the magnetic leakage is naturally very great, and the transformation ratio was only 1·38 on open circuit; while, if a condenser was in the secondary, of about 5 microfarads capacity, the transformation ratio rose 18 per cent.

On the other hand, if the magnetic leakage were reduced by completely superposing the primary and secondary, the ratio rose from 2·7 to 2·74, or only one and a half per cent. The author concludes that there is no reasonable doubt that in magnetic leakage lies the whole explanation of this phenomenon.

R. J. HOLLAND—ALTERATION OF THE CONDUCTIVITY OF A SOLUTION BY ADDITION OF SMALL QUANTITIES OF A NON-CONDUCTOR.

(*Wiedemann's Annalen, Vol.* 50, *No.* 10, *p.* 261.)

The author tried solutions in methyl alcohol of various salts, such as the nitrates of potassium, sodium, and ammonium, and several chlorides. The non-conductors were such as did not affect these salts—benzol, toluol, xylol, oil of turpentine, glycerine, &c.—and the determinations of resistance were by the Kohlrausch telephone method. The following were, briefly, the conclusions arrived at:—The electrical conductivity of a methyl-alcohol solution of an electrolyte diminishes

with the addition of a non-conductor by an amount varying with the nature of the non-conductor and its strength; the above-mentioned materials—benzol, toluol, xylol, and oil of turpentine—affect the conductivity in that order, the last being most powerful. The temperature coefficients of the alcoholic solutions become greater as the solution is made weaker; they are about half as great as those of the corresponding aqueous solutions, and are influenced to a very small extent by the presence of a non-conductor.

F. SCHULZE-BERGE—ROTATING AIR PUMP.

(*Wiedemann's Annalen*, *Vol.* 50, *No.* 10, *p.* 368.)

To combine the advantages of the high vacua produced by the Sprengel and Geissler pumps with a greater rapidity of working, the author has devised a rotating mercury air pump, here fully described. The pump vessel is a curved tube returning on itself, attached to an axis on which it can rotate. A mass of mercury flowing in the interior of the tube, and partially filling it, is arranged to produce the vacuum on one side and expel the air on the other, the connection to the pump vessel or the atmosphere being effected by suitable cocks or valves. The best form into which this pump has been developed is the one called by the author "double-"ring pump," in which the air expelled by the first tube has to pass the second before reaching outer air. It is of simple construction, and produces a very high vacuum by simple rotation, and can be belt-driven. When precautions are taken to have the apparatus and all its parts thoroughly dry, vacua can be obtained which surpass the limits of accurate measurements on McLeod's apparatus. The pump already made, having a capacity of about 1 litre in the ring (pump vessel), can be rotated about 15 times per minute.

G. DETTMAR—EXPERIMENTS ON "KRUPPIN," A NEW RESISTANCE MATERIAL.

(*Elektrotechnische Zeitschrift*, 1893, *No.* 50, *p.* 710.)

This is a new metallic alloy produced by Messrs. Krupp, of Essen, and distinguished by a high specific resistance. The accompanying tables and values give the qualities of the new material.

Specific resistance = 83 microhms per c.c.

This value is about 50 times that of pure copper.

Temperature coefficient = 0·13 % per 1° C

The following is a table of carrying power. The limit of temperature for the spirals is taken as that at which the wire "spits" when touched with the moistened finger. The spirals are in every case wound with that amount of spacing which is most favourable for the cooling of the wire.

Diam. Mm.	Resistance. Ohms per Metre.	Current Carried by Spiral.			
		In Air.		On Insulating Cylinder.	
		Constant Load.	One Minute Load.	Constant Load.	One Minute Load.
0·5	4·23	1·0	2·0	3·0	6·0
0·8	1·657	2·0	4·5	7·0	15·0
1·0	1·058	3·0	6·5	9·0	20·0
1·4	0·539	4·5	12·0	13·0	28·5
1·6	0·413	5·5	15·5	14·5	31·5
2·0	0·264	7·5	23·0	18·0	37·5
2·5	0·169	10·5	34·0	21·2	43·5
3·0	0·1175	14·0	45·0	23·5	48·5
3·5	0·0862	17·5	60·0	—	—
4·0	0·0661	21·5	75·0	—	—

J. KLEMENCIC—ABSORPTION AND DISTRIBUTION OF ELECTRIC OSCILLATIONS IN WIRE NETWORKS.

(*Wiedemann's Annalen, Vol.* 50, *No.* 11, *p.* 456.)

The author's method of measuring the energy converted into heat at any given point consists in placing close against the wire a thermo-electric couple of fine wires, from which he determines the amount of rise of temperature in the wire by means of its radiation on to the thermo-electric junction. The oscillations were produced in the manner described by Hertz. The exciter for the primary oscillations consisted of two brass plates of 30 cm. diameter, connected by a conductor containing the spark gap; the secondary inductor being precisely similar, but having no spark gap: this was replaced in the heating experiments by two experimental wires in series, and in the distribution experiments by the same wires in parallel. The length of these wires was, at most, 6 cm.; in a secondary conductor, 89 cm. long. The thermo-electric wires were at right angles to these, and were used with a Thomson-Carpentier galvanometer. The author arrives at the following conclusions:—The resistance on which the development of heat depends is, in the case of electric oscillations of great rapidity, determined by the material itself, and by its magnetic permeability. Wires of iron, German silver, brass, and copper, of 6 cm. length and 0·018 cm. radius, gave a development of heat approximately in the ratio of 10·5 : 1·75 : 1·0 : 1·0 (copper probably too large). Apply to these observations the Stefan formula,

$$V = \frac{r}{r_1}\sqrt{\frac{\mu\ \rho}{\mu_1\ \rho_1}},$$

where V is the ratio of the amounts of heat produced, r and r_1 the resistances, μ and μ_1 the magnetic permeabilities, and ρ and ρ_1 the specific resistances of two

wires of equal diameter and different materials, subjected to electric currents of the same strength and frequency; the author finds the formula fit well for the pair German silver-brass, but less well for German silver-copper.

The author finds, in addition, that, as was to be expected, the distribution of high-frequency oscillatory currents depends on the self-induction, and not on the resistance, of the branches of the network.

K. R. KOCH—A SIMPLE METHOD OF MEASURING THE CONDUCTIVITY OF DIELECTRIC LIQUIDS.

(*Wiedemann's Annalen*, *Vol.* 50, *No.* 11, *p.* 482.)

If a dielectric liquid possesses a conductivity electrolytic in its nature, then two electrodes connected with a battery will become polarised after immersion in the liquid for a certain time; and this phenomenon is best observed by Dewar's modification of Lippmann's capillary electrometer. A drop of the liquid under observation is placed in a horizontal tube about 1 mm. in diameter, which communicates on either side with vessels of mercury, and is filled up to the level of the communication tube with mercury. If the two sides are joined up to the poles of a battery, the drop begins to move in one or the other direction if the substance conducts electrolytically, and polarisation sets in at the mercury surface at the opposite side. With poor conductors the drop should not exceed about ½ mm. in length.

The author found that all dielectric liquids, without exception, that he tried, showed polarisation, and in the same sense; but he considers that this is in some cases due to impurities—for this reason, that if the current is left on, the movement of the drop is much less marked. The author took benzol, prepared in the highest possible condition of purity, and dried and cleaned all the apparatus, and used mercury after repeated distillation: it showed, just as commercial benzol did, strong polarisation. But when the mercury was poured in hot into a warmed electrometer (about 120° C.) there was no polarisation, even at high electro-motive forces; and the former polarisation was probably due to moisture on the surface of the mercury. The great advantage of the method is its extreme delicacy; but the difficulties of procuring perfect cleanliness in all parts are very great.

J. SAHULKA—MEASUREMENT OF THE CAPACITY OF CONDENSERS WITH ALTERNATING CURRENTS.

(*Elektrotechnische Zeitschrift*, *No.* 52, 1893, *p.* 739.)

The author calls attention to the fact that condensers with solid dielectrics have a greater capacity when measured with direct currents than that found by alternate-current methods; he explains this by the fact that "soaking" of the charge occurs with direct currents and takes an appreciable time, and that part of the quantity of electricity which passes into or out of the condenser by reason of this soaking is measured by the galvanometer in direct-current methods. When charge and discharge, on the other hand, take place with great rapidity, as in an

alternating-current method, there is no time for soaking, and the quantity passing in and out is therefore less. He proposes to define the capacity of a condenser for alternate currents as follows:—The capacity of a condenser in an alternate-current circuit is equal to the reciprocal of the product $2\pi n$, multiplied by the inductive resistance; the latter being the quotient of the volts in the condenser divided by the current flowing in its circuit. As an instance of the kind of difference which occurs, a condenser made of paraffined paper, and having a capacity of about 1 microfarad, was reduced in capacity by 14 per cent. on an alternating current.

G. U. YULE—ON THE PASSAGE OF ELECTRIC WAVE-TRAINS THROUGH LAYERS OF ELECTROLYTE.

(*Philosophical Magazine, Vol.* 36, *No.* 223, *p.* 531.)

Professor J. J. Thomson attempted in 1888 to compare the resistances of electrolytes with rapidly alternating currents, using electric radiation. He placed a dish containing the electrolyte in a thin layer between an oscillator and a resonator, under which circumstances, if the layer be thin, the thickness of liquid required to just extinguish the sparks is inversely proportional to its conductivity. The author, in repeating more accurately these experiments, propagated his waves between a pair of parallel wires of great length, a certain portion of which was immersed in the absorbing liquid; measurements were made by the electrometer. It was immediately noticed that the transmitted intensity, instead of decreasing logarithmically with increased thickness of liquid, decreased and increased periodically, and made an exact determination of the conductivity impossible; but the results are of interest, since they show interference phenomena analogous to those of light transmitted through thin plates. Independently of a slight absorption, a layer a quarter of a wave-length thick transmitted a minimum, one of half a wave-length a maximum, and so on. The effect is best shown in distilled water, where the absorption is very low, and the intensity has maxima at 0 cm., 55 cm., and 109 cm. thickness of dielectric; but is also well shown in alcohol, with a maximum at 0 cm. and 80 cm. (about). From these results the author calculates the dielectric constants of the various solutions experimented upon from the formula,

$$k = n^2 = \left(\frac{\lambda_a}{\lambda_s}\right)^2,$$

where k is the dielectric constant, n the coefficient of refraction, and λ_a and λ_s the wave-lengths in air and solution respectively; for small absorption the latter is taken as twice the distance of the first maximum from zero.

The values are as follows:—

Substance.	Refraction Coefficient.	Dielectric Constant.
Water	8·33	69·5
Zinc sulphate (different strengths)	8·49	72·0
	8·65	74·9
Alcohol (95 %)	5·17	26·7
3 vols. alcohol, 1 vol. water	5·84	34·1

Wave-length in air = 900 cms.

This result for water is rather lower than that obtained by other observers, whose values vary from 70 to 84 for the dielectric constant. This is accounted for by the fact that some of the wave flows outside the jar instead of through the liquid, and this portion shifts the maximum forward, making it more near to the air value.

A note follows on the theory of these effects.

ANON.—ETCHING BY THE AID OF ELECTRIC CURRENT.

(*Elektrotechnische Zeitschrift*, 1893, *No.* 44, *p.* 638.)

A wire is soldered to the plate to be etched, by means of which an electric current is passed through the etching solution, which is made much more dilute than in the case of ordinary etching. The action is much increased in intensity, and in many cases acids which under ordinary circumstances are inert, can be used; as, for instance, copper and weak sulphuric acid.

Some details of the process are given by the inventor.

P. BOUCHEROT—ON THE COST OF HIGH-PRESSURE LINES.

(*La Lumière Electrique*, *Vol.* 50, *No.* 52, *p.* 601.)

It has usually been the custom to give preference to continuous currents rather than to alternating currents for purposes of transmission of power, on the ground that 1,000 effective alternating volts correspond to a maximum P.D. of 1,400 volts; and consequently the line for an alternating current will cost twice as much as a continuous-current line for the same power, as the weight of copper for equal efficiencies varies inversely as the square of the voltage.

Experience has proved this reasoning to be erroneous, since the pressures used with alternating currents are considerably above those for continuous currents; another advantage in favour of the former being the absence of electrolytic action in the case of leakage, but a disadvantage is that for the same power and voltage the mains have to be larger in section for alternating currents, on account of lag due to self-induction. Lines may be roughly divided into two large groups—overhead and underground.

It is difficult to apply Lord Kelvin's rules to underground lines on account of the heavy insulation, which necessarily alters with the pressure employed, and also on account of their capacity. Lord Kelvin has shown that the total cost of transmitting energy through a wire is a minimum when the value of the power annually dissipated in heat in the wire is equal to the interest on the capital outlay on the conductor.

The annual cost of transmitting energy consists of two parts—energy lost in the conductor itself, and interest and depreciation on the capital. Approximately, the loss of energy in the conductor is inversely proportional to the cross section of the line.

The annual expenditure may be expressed algrebraically,

$$\frac{\alpha}{s} + \beta s.$$

The product of these terms remains constant; the minimum value may correspond to

$$s = \sqrt{\frac{\alpha}{\beta}}, \text{ or to } \frac{\alpha}{s} = \beta s.$$

The cost of the line itself may be divided into two parts—the cost of laying, and of insulating supports, these being almost independent of the section of the line; and, secondly, the cost of copper.

In certain cases Thomson's rules assume different forms—for instance, when it is a question of utilising water power; but in either case the result is independent of the length of the line; for each of the terms involved increases proportionally with the length of line.

The problem of economical transmission through an overhead line with any given pressure is simpler than with an underground line.

Assuming no capacity in the system, the annual expense is then the sum of the following items:—

(1.) The cost of waste energy per annum, which is inversely proportional to the square section.

(2.) Interest on capital outlay on copper, which is proportional to section.

(3.) Interest on capital outlay on insulation, depending on the voltage, since this determines the amount of insulation.

This third part may be considered as proportional to voltage and to the diameter of cable. As in most cases, V is determined beforehand. The minimum cost then becomes,

$$\alpha + \beta s^{-\frac{1}{2}} = s^{-2},$$

or which may be written,

$$\alpha s^2 + \beta s^{\frac{3}{2}} = 1 \quad \dots \quad \dots \quad \dots \quad \dots \quad (1)$$

It may be necessary in cases to find the most economical voltage to use, for in the case of underground lines it is not the highest voltage which gives maximum economy, on account of the heavy insulation necessary.

The minimum cost may then be taken as,

$$\alpha + \beta V s^{\frac{1}{2}} = s^{-2} \quad \dots \quad \dots \quad \dots \quad \dots \quad (2)$$

The three following points deserve attention:—

(1.) If we suppose the voltage to vary, with the assumption that the loss in line is a constant, then the section or price of copper will vary inversely as the square of voltage.

The price of insulation is determined by its thickness, which is proportional to voltage, and its circumference is proportional to the square root of the section—that is to say, inversely proportional to the voltage; its price then remains constant, whatever be the voltage.

The annual cost is then the sum of three terms, two of which are constant (loss and insulation), and the third inversely proportional to square of voltage. It then becomes an advantage to raise the voltage.

(2.) If, on the other hand, the weight of copper is to be a constant, the price of the insulation will be proportional to V. The annual expenditure will in this case be the sum of three terms, two being constant, and the third proportional to V. It will then be an advantage to diminish V.

(3.) And, lastly, if one considers the condition of minimum cost to be realised in the absence of insulating material, considering only copper and loss, and then consider the cost of copper and insulation to be a minimum, the following result is arrived at:—The price of copper, by hypothesis, is inversely proportional to V. The price of insulation will then be proportional to V, and to the square root of the section, or inversely to V. Then

$$\frac{V}{\sqrt{V}} = \sqrt{V}.$$

The annual expenditure will be,

$$\alpha V^{-1} + \beta V^{\frac{1}{2}}.$$

α includes the coefficients for the copper and loss of energy, which becomes a minimum when

$$V = \frac{\beta^2}{4\alpha^2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

By formula (2) the voltage may be determined, and by (1) the section, and from these two formulæ a very close approximation may be arrived at for the true section. This will, however, not be quite correct in actual practice, on account of the ambiguity existing between makers as to the right thickness of insulation for various voltages.

In the case of alternating currents capacity and self-induction must be considered.

Let E and I be taken for the E.M.F. and current in the receiving apparatus: then power transmitted is E I cos ϕ.

If a condenser of capacity C be placed in shunt to the end of the line, then

$$C = \frac{I \sin \phi}{E \omega},$$

and I s ϕ represents the current.

The current passing through the line is I cos ϕ, instead of I.

The capital expended in the line may then be reduced in the ratio of 1 to cos ϕ, and the annual loss in line may be reduced in the same ratio.

The cost of condenser will be,

$$\gamma E^2 C = \gamma \frac{E}{\omega} I \sin \phi,$$

in which γ is the price of a condenser of 1 microfarad to work at 1,000 volts. If we assume that 20,000 watts are to be transmitted at 2,000 volts with a lag of $\frac{1}{8}$ period, this will necessitate the transmission of 28·3 amperes.

Assume, moreover, that the most economical case corresponds to a drop of 10 volts per km. If the distance be 10 km., the total drop will be 200 volts; and without a condenser the line resistance = 7·07 ohms. The section will then be 48 sq. mm., and the copper will cost 17,000 to 18,000 francs. The annual cost of the line will about be

$$2 \times \frac{5}{100} \times 18{,}000 = 1{,}800 \text{ francs},$$

which includes loss of energy and interest.

With a condenser, however, the line will have to carry only 20 amperes, and may then have 10 ohms resistance, the section being 34 sq. mm., and will cost 12,000 francs; the annual cost being about 1,250 francs.

The author then considers the transmission of power along a line between two synchronous machines.

For perfect stability of running, the inductance of the circuit should be equivalent to its resistance. Consequently, in the case of alternators with iron in the armature, it is not rare to find the inductance from 25 to 30 times greater than the resistance.

If the inductance of the line is about equivalent to the sum of the resistances in the two machines, the inductance is still from 12 to 15 times greater than the resistance. For this reason the machines may be unstable; and the current passing through the machines for producing a certain amount of work is 15 to 20 per cent. greater than that which would be necessary if the inductance were equivalent to resistance.

The addition of a condenser in series with the circuit of such a system gives the following results:—

(1.) Diminution of capital involved in the machines.

(2.) Diminution of capital involved in line.

(3.) Increase in output of dynamos.

(4.) Increase in efficiency of line.

(5.) Increased stability of system and stability of running.

The above considerations apply equally well to polyphase currents

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ANON.—THE ELECTRIC LIGHTING OF DIEPPE.

(*La Lumière Electrique, Vol.* 50, *No.* 44, *p.* 209.)

The town of Dieppe, previous to the present electric light installation, had only a few hundred incandescent lamps, supplied from gas engines and accumulators.

On account of the increased demand, a company was formed with 120,000 francs capital for the purpose of supplying electricity on a large scale.

The dynamos, switch-boards, apparatus, and mains were supplied by the firm of Gramme. The central station is situated near the harbour, the building being 23 metres long and 10 metres wide, with sufficient space for further extensions. The output of the station is 100 H.P. Two Boulet vertical compound non-condensing engines are used, each giving 40 H.P. with 6 atmospheres pressure at 260 revolutions per minute; they will, however, give 50 H.P. with 8 atmospheres pressure.

Steam is supplied to these engines from four Paxman boilers, an existing tubular boiler being used as a reserve. The present height of the chimney shaft is 25 metres, but will allow of 6 metres extension. Water is obtained from the town mains, and paid for at the rate of 0·08 franc per cubic metre.

Worthington feed pumps and a Giffard injector are employed.

Each steam engine drives two Gramme dynamos, running at 1,100 revolutions per minute, and giving 130 volts and 90 amperes under normal conditions. Next to the dynamo room are installed two batteries of accumulators of 144 elements, containing 33 kilogrammes of plates per cell, with a capacity of 250 ampere-hours.

The cells are of the Verdier type, the plates being placed horizontally, and

having perforations for the free circulation of liquid and liberation of gas. This position of the plates also prevents short-circuiting.

The three-wire system is adopted, with 260 volts between the outside wires. Alarm bells are used for indicating too great variations in the voltage.

Three feeders leave the station, which meet outside to be connected in parallel, giving a total section of 80 square millimetres, the wires running overhead.

At present the full output is 1,200 to 1,300 10-C.P. lamps; the prospective supply is for 2,000 lamps, which will necessitate extensions.

The price of the hectowatt-hour is 1·20 francs.

A. HESS—THE PART PLAYED BY CAPACITY IN ALTERNATING-CURRENT CIRCUITS.

(*La Lumière Electrique, Vol.* 50, *No.* 47, *p.* 380.)

The author calls attention to the important capacity effects which take place on the circuits used in actual practice.

First consider two cables, A and B, lying on the ground. Each cable has a capacity C with respect to the earth, and which is distributed along the conductor.

If there exist an alternating P.D. between the two cables, a condenser current will be set up. This current does not, however, represent a dissipation of energy, as it is in quadrature with the P.D.; this was pointed out by M. Boucherot in 1890.

Although the insulation resistance between the cables may be very high when there is no P.D., under actual working conditions this insulation resistance may become many thousand times lower. As in actual practice there exists a certain resistance between the two cables, the difference in phase between current and P.D. is no longer exactly a quarter of a period, and the product of the two factors represents a certain amount of power dissipated as heat in the earth. When the cables are so close together that there is appreciably no resistance between their outer surfaces, there will be no loss under normal conditions.

If by accident one of these cables is put to earth, there will be a loss of energy, which becomes a maximum when a certain resistance is in circuit.

Concentric cables forming a closed circuit do not produce a loss of energy, so long as the conductors are well insulated from one another. But if the inside conductor be put to earth through a resistance R, a condenser current is set up which represents a loss of energy, dependent on the value of the resistance R.

Overhead lines may produce analogous effects on a much smaller scale when they are brought near objects in contact with the earth, or when the conductors are very distant from one another. M. Claude has recently suggested methods for obviating these losses, and preventing other objectionable effects.

Although conductors may offer an insulation resistance of hundreds of megohms, it is quite possible that grave accidents may happen when the human body makes contact with one pole only. In such a case capacity is playing the most important part.

A capacity C charged by alternating currents of a frequency ω offers to such

currents an apparent resistance $\frac{1}{\omega C}$, which may be equivalent to only a few thousand ohms for the best insulated cables, and is the only thing which prevents a short-circuit when the cable is touched. If one of the wires of a system working at 2,400 volts were touched, at that moment there would be a P.D. of 1,200 volts between the wire and earth. If R represent the resistance of the body, then the current flowing will depend on the total apparent resistance,

$$\frac{1}{\omega c}\sqrt{\frac{4 C^2 \omega^2 R^2 + 1}{C^2 \omega^2 R^2 + 1}},$$

and the body is subjected to a P.D. of

$$\frac{E C \omega R}{\sqrt{1 + 4 R^2 C^2 \omega^2}} \sin \omega t.$$

The higher the resistance the higher the voltage, which in the present case may reach 1,000 volts. Considerable danger may then arise from touching one pole, due solely to capacity effects.

In the case of concentric cables, the capacity between the external wire and earth produces an analogous effect when the inside conductor is touched. M. Claude has recently suggested the use of self-induction to get rid of these effects, which would be placed in shunt to the capacity.

The resistance of the C L path then becomes $\frac{1}{\frac{1}{\omega L} - \omega C}$, which increases when $\frac{1}{\omega L} - \omega C$ diminishes, and becomes infinity when $\omega^2 L C = 1$. Or, in other words, the sum of the currents in the C L branch should $= 0$.

One current, $$i_c = C\frac{de}{dt};$$

the other current, $$i_L = \frac{1}{L}\int e\,dt;$$

and if $$e = e_0 \sin \omega t,$$

then, to make $$i_c + i_L = 0,$$

$$C e_0 \omega \cos \omega t - \frac{1}{L \omega} \cos \omega = 0,$$

or $$\omega^2 L C = 1.$$

In practical working, L itself will offer a certain resistance, and consequently it will not be possible to obtain an infinite resistance without complicating matters.

M. Claude's suggestions are, however, open to some criticism. Between each cable and earth there exists a P.D. of, say, 1,200 volts. When contact is made through the body between one wire and earth, the P.D. becomes 0, and consequently no current passes; but the 1,200 volts do not die down instantly, the time taken depending on a term E^{kt}, and on the time constants of the capacities and self-induction. The body is therefore subjected to pressures of from 1,200 volts to 0. The change is so rapid that the physiological effect may not be dangerous—a point which is open to some discussion. But, apart from this, an advantage of the system is that the capacity losses have been reduced.

It is then advisable to reduce the capacity of the mains as much as possible, which can be done by allowing sufficient distance between the cables and earth;

but the capacity between the cables themselves is reduced, which capacity is rather an advantage for annulling the self-induction of the dynamos.

If concentric cables are used, it is possible to diminish the capacity between the cables and earth without diminishing the capacity between the wires themselves.

G. VASSURA—ON THE ELECTRICAL RESISTANCE OF CERTAIN METALS AT MELTING POINT.

(*Journal de Physique, December*, 1893, *p.* 577.)

The author has determined the electrical resistance of tin, bismuth, and cadmium at their melting points; the purity of the metals being ascertained by spectrum analysis.

The resistances were measured by the Thomson method in capillary U tubes, which had been previously filled with mercury and their resistances taken. These tubes were filled with the molten metals in a vacuum, and at a high temperature.

Calling τ the melting temperature of the metal, and $K_{L,T}$, $K_{S,T}$, $K_{S,0}$ the resistance of the molten metal and the solid metal at τ, and solid at 0°, the following results are obtained:—

	τ.	$\frac{K_{L,T}}{K_{S,T}}$.	$\frac{K_{S,T}}{K_{S,0}}$.
Tin...	226°	2·126	2·225
Bismuth	271°	2·466	2·126
Cadmium	318°	1·976	2·664

J. LEFEVRE—RESEARCHES ON DIELECTRICS.

(*Journal de Physique, December*, 1893, *p.* 561.)

In an electro-magnetic field, produced by a single point, A, is placed the dielectric, with plane faces parallel to one another. It is necessary to find how the value of the potential has been modified on the opposite side of the dielectric. A Coulomb balance was used for this purpose, and Poggendorf's method employed for reading deflections. A compensator was used, consisting of two spheres, or of a plate and sphere so placed as to annul any external disturbances on the needle, supported by a bifilar suspension. When the needle is at zero, the dielectric is introduced between the two spheres. The needle and compensator are then charged, and the fixed sphere is so manipulated as to maintain the needle at zero. The fixed sphere is then charged, and is moved up to successive distances from the movable sphere. For each position the repulsion is balanced, and the needle brought back to zero by twisting the bifilar suspension.

The experiment is repeated without any dielectric in the instrument. Corrections are necessary in the torsion readings, for the mutual influence of the two spheres, and for the torsion of the bifilar, which does not quite follow a sine law.

After making these corrections, two curves are plotted, with distances of the spheres for abscissæ and the torsion readings, with or without the dielectric for ordinates. These curves show that the effect of the insulation is the same as though

the spheres were brought nearer to one another by a distance δ, which seems to be proportional to a thickness e, and to vary with the nature of the material.

Then $$\delta = e f(K),$$

K being the dielectric constant.

The distance δ can be measured directly from the curves, and then $f(K)$ deduced from it, of which the values are given in the table below.

The author has tried the following empirical forms for $f(K)$:—

$$(1)\quad \frac{K - 1}{2},$$

$$(2)\quad \frac{K - 1}{K},$$

$$(3)\quad \frac{3}{2}\,\frac{K - 1}{K + 2},$$

$$(4)\quad 2\,\frac{K - 1}{K + 2},$$

which give identical results for K = 1 and K = 2. The following table, giving the four values of K for various substances, agrees fairly well with Mr. Gordon's results. The values of K seem most consistent for the same substance. The mean values for sulphur and for glass are a little below Gordon's results.

Substances.	e.	δ.	$f(K)$.	K_1.	K_2.	K_3.	K_4.
Brown paraffin ...	3·54	1·775	0·50	2·00	2·00	2·00	2·00
White „ ...	3·90	2·15	0 55	2·10	2·22	2·15	2·13
Ebonite, No. 1 ...	2·72	1·50	0·55	2·10	2·22	2·15	2·18
„ No. 2 ...	2·12	1·275	0 60	2·20	2·50	2·33	2·28
St. Gobain glass, No. 1	1·73	1·2	0·69	2·38	3·22	2·70	2·58
„ No. 2	2·50	1 4	0·56	2·12	2·27	2·19	2·16
Sulphur, No. 1 ...	2·87	1·825	0 63	2·26	2·70	2·44	2·38
„ No. 2 ...	4·50	3·00	0·66	2·32	2·94	2·57	2·47
„ No. 3 ...	3 60	2·10	0·58	2·16	2·38	2·26	2·22
Sulphur, No. 4, melted since six months	2·46	1·80	0 73	2 46	3·70	2·89	2·72
Essence of turpentine	3·00	1·10	0·37	1·74	1·58	1·65	1·68
Sulphide of carbon	3·00	1·275	0·42	1·84	1·72	1·77	1·79

P. MARCILLAC—THE TIVOLI-ROME TRANSMISSION OF ELECTRICAL ENERGY.

(*La Lumière Electrique, Vol.* 50, *No.* 44, *p.* 209.)

The author continues a description of the system, and enters into details of the line.

An overhead line is employed from Tivoli to Rome. The posts carry an oak beam at the top, to which are fixed four brackets, to which are fixed porcelain insulators of the usual type, placed at a distance of 0·6 metre from one another. Four high-tension wires are run in this manner. An outside iron shield is used to support the wire in the event of its leaving the insulator.

The top of the post carries a lead cap, over which is fixed a lightning

conductor. Below the high-tension line are fixed four small insulators carrying four phosphor-bronze wires for transmitting telegraphic and telephonic messages.

In order to minimise the effects due to induction, the telephone and telegraph wires are alternated at every tenth post. Most of the posts carry light insulators. The height of a post above ground is 9·5 metres.

There are altogether 707 supports for the line, and the mean distance between supports is 35 metres, the maximum distance being 40 metres.

The four wires are at respective heights of 9·3, 8·7, 8 1, 7·50 metres from the ground.

The insulation of the line is 3,250 megohms per kilometre. The copper is of 99 per cent. conductivity. Each line has a section of 104 square millimetres, and a resistance of 8·750 ohms at 0°.

The Porte Pie Central Station.

This forms the terminus station in Rome. The pressure is here transformed down to 2,000 volts. Siemens concentric cables are run from the station into the principal thoroughfares of Rome for purposes of public and private lighting. The basement of the station is divided into two parts. One contains 32 30-kilowatt transformers, run from the four line wires; and in the other is placed the instrument and distributing board.

Series arc light circuits are run from the station, and consist of Siemens concentric cables with a section of 12 + 12 $mm.^2$, worked directly from a transformer in the station.

Private lighting is worked at 50 volts or 100 volts pressure from sub-stations connected to the central station by Siemens concentric cables of a section of 220 + 220 $mm.^2$. The station transformers are divided into two groups: one group of 16 is used for the municipal lighting, and the remaining 16 for private lighting circuits.

These transformers have a ratio of transformation from 2 : 1; resistance of primary, 3·1 ohms; resistance of secondary, 0·75 ohm; output of 30,000 watts, or secondary current of 15 amperes at 2,000 volts; full-load efficiency, 97 per cent.; insulation resistance between primary and secondary of 7,000 megohms.

On the switch-board small transformers are used for reducing the volts from 18 to 1, with a Cardew voltmeter on the secondaries. The transformers used for the series arc lighting have the secondaries wound in four sections, each one giving 500 volts. A multiple-contact switch will allow of any number of the sections being used. A Blathy regulator is used for maintaining a constant current There are altogether 12 of these series circuits.

If five of the six alternators installed at Tivoli be working simultaneously, and each delivering 42 amperes at 5,100 volts, the line will have to carry 210 amperes The resistance of the line when all four wires are in use is 3·75 ohms. The drop in potential will be 210 × 3·75 = 787·5 volts, or 15·4 per cent. drop.

If the transformers at the Porte Pie station lose 3 per cent. at full load, the total loss then becomes 17·9 per cent

Town Lighting.

Four Siemens concentric cables, 220 + 220 $mm.^2$ section are laid from the Porte Pie station into the town. These cables have a length of about 9 kilometres.

The series arc light circuits have a total length of about 28 kilometres. Each circuit has 33 or 34 lamps, which makes a total of 203 lamps for the six circuits in actual use. The lamps, which are placed 40 or 50 metres apart, at heights of 8 to 10 metres from the ground, are of the Zipernowsky differential focusing type, give 800 candle-power with 14 amperes working at 88 volts, and will burn for 14 hours without requiring new carbons.

L. MORISSE—AMERICAN GUTTA-PERCHA.

(Annales Telegraphiques, Vol. 20, p. 352.)

M. Séligmann was the first to remark that all gutta-percha trees were found between the same parallels of latitude. The names given by the Indians to the four gutta-percha trees are the Pindare, Masarandu, Marima, Balata; all of which possess distinct characteristics. The zone in which the above trees are to be found is approximately bounded by the 6th degree of latitude N. and S. of the Equator. These trees are to be found in almost every part of this zone, although the configuration of the soil in places does not admit of their growth.

M. Sérullas maintains, however, that, accurately speaking, the habitat of gutta-percha trees is bounded by isothermal lines, and the territory enclosed by the two lines corresponds very nearly with the zone enclosed by the 6th degree of latitude N. and S.

The growth of the gutta-percha tree is very much modified according to the geological conditions of the district.

On American soil, gutta-percha trees require considerable moisture, preferably low-lying, sheltered ground, with an even temperature—in short, a Silurian soil, easily flooded with a small rainfall. The trees are not to be found on mountains or on alluvial plains.

The Balata tree requires from 1 to 1·5 metres of vegetable soil, with a damp and porous subsoil. The four above-named trees all grow to about the same size. The size of the trunk is about that of a man's body, and the tree grows to a height of about 18 or 20 metres. The trunk is smooth, and generally quite straight up to the first branches, which are at about 6 to 10 metres from the ground.

The Pindare tree is the one which yields most gutta-percha; the milk is clear, and flows freely from incisions made in the trunk. The flow from each incision lasts about a quarter of an hour. The author has in cases made as many as 30 incisions in the same tree, and obtained 500 grammes of the milk.

If incisions are made round the trunk at the junction of the branches, in order to stop the flow of sap into the leaves, as much as 5 or 6 litres of the milk may be obtained from one tree in a few hours.

The Marima tree yields a good quantity of the milk, which is clear, and of a viscous and gummy nature.

The milk of the Pindare tree coagulates only in the shade at the end

of 36 hours at a temperature of 30°, and takes from 13 to 14 hours to coagulate; the liquid which remains after coagulation, instead of being clear, as in the case of the Marima, is of a milky colour, and when evaporated and treated with potash will coagulate and form an excellent gutta-percha. The process requires great care, as the products are easily burnt with too high a temperature. The sun's heat at mid-day is sufficient for the process.

Balata trees may be divided into two classes—the red and white; the former is the commoner of the two, and the one of commercial value. The red Balata is essentially an American tree; it flourishes in the Guianas and in Venezuela, in great numbers. Its large size, abundance of sap, and its vigorous nature rank it amongst the best gutta-percha trees of the future.

Incisions in the tree may be made in the usual manner. The milk coagulates slowly, and consequently does not close up the incisions too quickly.

From 10 to 14 incisions must be made in an oblique direction in three or four vertical lines; to obtain a good quantity it is necessary to use a ladder reaching to a height of 2·5 or 3 metres. If the tree is cut in the right manner, from 150 to 200 grammes should be obtained every two days.

The author does not advocate cutting down the tree, which, in cases, is a tedious and difficult operation. It may, however, on some occasions prove advantageous. The best method of procedure is then to completely strip the tree of its bark, which must be cut up into small pieces and placed in an equal weight of water, made alkaline with potash, and kept at a temperature of 30° or 35°. The pieces of bark are then removed and subjected to a considerable pressure in a wooden press. The milk thus obtained is of an excellent quality; it must be mixed with water from the above bath, strained, and then evaporated during 24 hours at 40° or 45°. The product must then be placed in a suitable churn in the presence of phenic acid. The temperature of the bath and time taken for the above operations are of considerable importance. The gutta-percha thus obtained is of the finest quality, and equal to the best Isonandra percha. It is of a solid and unchangeable nature, and of a pinkish-white colour.

The milk of the Masarandu tree possesses many interesting characteristics. It is very thick, and rapidly coagulates on exposure to the air, which makes it very difficult to collect.

It contains about 60 per cent. of its weight of water, which takes a considerable time to eliminate. The best method of doing this is to treat it with hot water at 70°, and then well compress the coagulated mass, which will then form an excellent gutta-percha without any chemical or antiseptic treatment. It is difficult to collect the milk of the Masarandu tree, on account of its viscosity; the quicker way is to partially bark the tree, and if about one-third of the bark be left on the tree it will not die. If, however, it be completely stripped, it will die in a very short time. The bark must be washed in water at 50°, containing a small quantity of potash or soda. It must then be well scraped with a knife, and pressed. The thick juice which flows out soon becomes plastic. It must then be warmed to 70° and laminated with wooden rollers. The thin sheets must be beaten and again laminated, in order to get out all the water, which is charged with resin. Special manipulation is required in this process. The gutta-percha thus obtained is of a very good quality

Owing to the characteristic of each species, different methods of procedure are necessary. When, however, several of the species are to be found in the same place, it would considerably facilitate matters if one process only could be employed. The author tried to treat the mixture of the different milks with such dehydrating compounds as sulphuric acid or alcohol, but without success; and came to the conclusion that such a mixture will not coagulate when treated chemically, as in the case of caoutchouc. An application of heat invariably burnt the product, and therefore proved a failure.

The author then had recourse to mechanical separation of the globules from the water in which they form an emulsion. First attempts proved successful, and the method may be summarised as follows:—

(1.) The process of coagulation.

(2.) The disinfecting and antiseptic process, carried out simultaneously in one operation.

Rapid coagulation takes place when the milks are mixed and churned in a centrifugal turbine with a continual admission of commercial phenic acid (not crystallised), to ensure an antiseptic effect. The mixture should be previously warmed to 40°, and the process of coagulation and disinfection carried out in sunlight from 10 a.m. to 3 p.m. One litre of impure phenic acid is sufficient for 20 litres, or 12 to 13 kilogrammes of gutta-percha. The turbine should be capable of coagulating 10 litres of the milk in less than one hour.

A 10 per cent. alcoholic solution of corrosive sublimate was tried as a disinfectant, and the resultant gutta-percha was of fine quality; it is, however, to be feared that the presence of bichloride of mercury would prove detrimental in commercial applications.

The gutta-percha is obtained in sheets 60 cm. wide, 1·50 metres long, and 2 mm. thick, stuck on to a band of tissue, from which they are eventually separated. These sheets must be well washed in hot water, then beaten, and finally dried in the shade.

The author points out that, although no material has ever proved equal to gutta-percha as an insulator, it must be of the best quality and carefully prepared for it to maintain its position, and not rapidly deteriorate.

Although the Isonandra percha, from which rubber has been previously obtained, is becoming very scarce, the enormous numbers of Pindare, Masarandu, Balata, and Marima trees in the American forests should guarantee a large supply for many years if their products can only be utilised, and the author has endeavoured to explain the methods for doing so.

CLASSIFIED LIST OF ARTICLES

RELATING TO

ELECTRICITY AND MAGNETISM

Appearing in some of the principal Technical Journals during the month of DECEMBER, 1893.

S. denotes a series of articles. I. denotes fully illustrated.

LIGHTING AND POWER.

J. VIOLLE—Electric Furnace: Light and Heat of the Electric Arc.—*Jour. de Phys.*, December, 1893, p. 545 (I.).

E. MASSON—Electric Safety Cables for Use in Mines.—*Bull. Soc. Belge*, vol. 10, No. 6, p. 213.

J. DERY and L. WEISSENBRUCH—Electric Train Lighting.—*Bull. Soc. Belge*, vol. 10, No. 8, p. 239.

E. MASCART—Alternate-Current Motors.—*Bull. Soc. Int.*, vol. 10, No. 101, p. 345.

ANON.—Canalisation in the Streets.—*Bull. Soc. Int.*, vol. 10, No. 102, p. 419.

G. CLAUDE—On the Means of Increasing the Security of Distribution by means of High-Pressure Alternating Currents.—*Bull. Soc. Int.*, vol. 10, No. 103, p. 435 (I.).

— DEVAUX—Electric Tramways and Telephones.—*Ann. Tel.*, vol. 20, p. 330.

P. MARCILLAC—The Tivoli-Rome Transmission of Electrical Energy.—*Lum. El.*, vol. 50, No. 44, p. 209 (S. I.).

A. BLONDEL—On the Subject of the Unit of Light.—*Lum. El.*, vol. 50, No. 44, p. 222.

G. RICHARD—The Mechanical Applications of Electricity.—*Lum. El.*, vol. 50, No. 45, p. 251, No. 49, p. 458 (S. I.).

D. FARMAN—A New Electric Drill.—*Lum. El.*, vol. 50, No. 45, p. 264 (I.).

G. RICHARD—Arc Lamps.—*Lum. El.*, vol. 50, No. 47, p. 363 (S. I.).

G. RICHARD—Electric Rail and Tram Ways.—*Lum. El.*, vol. 50, No. 48, p. 401 (S. I.).

ANON.—The Electric Lighting of Dieppe.—*Lum. El.*, vol. 50, No. 48, p. 419 (I.).

G. RICHARD—Electric Welding.—*Lum. El.*, vol. 50, No. 50, p. 510, No. 51, p. 563 (S. I.).

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P. BOUCHEROT—On the Cost of High-Pressure Lines.—*Lum. El.*, vol. 50, No. 52, p. 601.

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／JOURNAL

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The Two Hundred and Fifty-ninth Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, February 8th, 1894—Mr. ALEXANDER SIEMENS, M. Inst. C.E., President, in the Chair.

The minutes of the Ordinary General Meeting of January 25th, 1894, were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Students to that of Associates—

Geoffrey F. R. Barrett.
John F. M. Bennett.
Herbert H. Berry.
Ernest Crocker.
Henry Joseph Garnett.
Henry Leslie Harris.
Frederick N. Haward.
Arthur C. Heap.
Walter H. Jackson.
Robert Andrew Miles.
Sydney W. Mitchell.
Charles Edward W. Talbot.
William G. Wallace.

Donations to the Library were announced as having been received since the last meeting from Messrs. Cassell, and Mr. Charles Bright, Member, to whom the thanks of the meeting were duly accorded.

Mr. A. T. Snell and Mr. F. C. Raphael were appointed scrutineers of the ballot.

The following paper was then read:—

SOME NOTES ON THE ELECTRIC LIGHTING OF THE CITY OF LONDON.

By Major-Gen. C. E. Webber, C.B., (Ret.) R.E., M. Inst. C.E., Past-President.

General Webber.

To the industry generally the history of the inception, and of what led up to the accomplishment, of the public lighting of the streets of that part of the metropolis known as the City of London may have, for several reasons, a special interest, and be worthy of record.

By those who may not already know it, it should be understood that the Commissioners of Sewers hold a similar position, and have similar powers to those that were possessed by the Metropolitan Board of Works and by the London Vestries before the London County Council came into existence; in fact, they are the local authority, possessing jurisdiction distinct from that of the Corporation, the Common Council, the Bridge House Committee, and such bodies; having the direction and control of expenditure on works, for which purposes their engineer and surveyor is Mr. William Haywood, C.E., a gentleman distinguished no less as a colonel of Volunteers, late and for many years commanding the 1st London Rifle Volunteers,* than as an engineer.

I think there is a good deal in which the question of what led up to the lighting of the City by electricity so much differs from ordinary cases, that a slight sketch of its history—which has never, I believe, been published—is not out of place on the present occasion. The City is at the head of our municipal institutions, both as regards antiquity, wealth, and organisation. From an imperial point of view, it is regarded as the heart of the commerce of the world. In respect to public lighting by electricity, I believe I can show you that it also has taken the lead.

In 1878, when the Municipality of Paris celebrated the International Exhibition of that year by lighting the Avenue

* Colonel Haywood joined the corps in 1859 as a private, and rose through each rank to be Lieut.-Colonel in 1876, and retired from that position in 1882.

de l'Opera with Jablochkoff lamps, run with Gramme machines by the Société Générale d'Electricité, Mr. William Bassingham, deputy-chairman, and Colonel Haywood, engineer of the Commissioners of Sewers, severally reported to the Streets Committee, in such detail, and in such terms, as to ensure the question never being dropped until the accomplishment of the results which we can nightly witness at the present time.* General Webber.

It is nearly 15 years since the date of those reports—years that have been momentous to all of us electrical engineers.

Colonel Haywood's report could not have dealt more exhaustively with the question, subject to the difference in knowledge at the present day, than if it was now to be compiled. He pointed out that no section of the metropolis was more interested than the City in obtaining an efficient illuminant, for, that within its boundaries the Gas Light and Coke Company then collected a rental of £370,000 per annum.

No doubt that example of street lighting in Paris induced the Commissioners to take up the subject. The 64 electric lamps in a thoroughfare 980 yards in length, placed 30 yards apart on alternate sides, were said to give a nominal candle-power of 20 times that of the 300 gas lamps previously used, allowing that one Jablochkoff candle gave 100 times as much light as a gas burner using 12-candle gas at 5 feet an hour.

The cost price of these lamps (estimated then at 6d. an hour), as they were extinguished at midnight, was £50 a year each, which, for 64 lamps, came to £3,200 a year, as against the cost of the gas lighting during the same hours, which came to £1,200 a year at 5 centimes per gas lamp an hour.

Colonel Haywood at that time considered that the Avenue was lighted "vastly in excess of all reasonable requirements;" and although he went no further than stating that in his opinion there were places in the City—such as by King William's Statue, in front of the Mansion House, and in the Circuses—where the convenience

* As international juror for telegraphs and allied electrical applications of that year, my notes on the installation show that the Avenue and Place de l'Opera and the Place du Théâtre Français, only represented a small fraction of the application of the Jablochkoff lamp then running in France.

General Webber.

of the large traffic "might justify the expense of employing the "electric light during the busiest hours of darkness," he nevertheless recommended the Commissioners, "that as early as possible "an ample experiment be made by lighting with electricity during "the winter months of 1878 one or more of the public thorough-"fares within their jurisdiction."

In consequence, in November, 1878, the same company commenced lighting the Holborn Viaduct with 16 Jablochkoff lamps, placed about 110 feet apart. They were run from sunset till midnight, replacing 86 gas lamps.*

The results arrived at after three winter months' work were, that, while only doubling the light (allowing a loss of 50 per cent. with the globes) of the 86 gas lamps, the cost—namely, 5·73d. per hour of 16 Jablochkoff lamps—was four times that of gas at ¼d. an hour.

The discouragement produced by this experiment only continued for one year, and in the spring of 1880 the Commissioners (at the instigation of several members whose names have since been connected with improvements in lighting the City) again decided to renew experiments on a more extended scale by lighting (see streets shaded black on map, Plan No. 1) New Bridge Street, Queen Victoria Street, Queen Street and Queen Street Place, King William Street to the Bank, Poultry, Cheapside, St. Paul's Churchyard, Ludgate Hill, New Bridge Street and the Bridge.

The thoroughfares in which the trials were to be made were divided into three districts, and out of six competitors who tendered in October, 1880, the following were selected. The contract was for one year, ending the 1st April, 1882. The Blackfriars Bridge district was allotted to the Brush Company; the Southwark Bridge district to the Electric Light Power Generator Company (Lontin system); the London Bridge district to Messrs. Siemens.

In June, 1882, Colonel Haywood reported that, allowing 50

* At the same time the Metropolitan Board of Works had been making experiments with the same company's plant on the Victoria Embankment, including photometric comparison of the gas and electric light.

per cent. of loss through the use of globes in the several districts, the increased light afforded, and the cost of the same under the tenders, in proportion to that of gas, were— General Webber.

		Increased Light.	Relative Cost.
No. 1 (Brush) ...	...	15	About the same.
No. 2 (Lontin) ...	...	14	Twice.
No. 3 (Siemens) ...	...	13½	3¾.

Thus the City of London had taken the lead in making a practical experiment on a large scale.*

The encouragement afforded by the results may be estimated by the following:—

(*a.*) The Commissioners decided to experiment again in four additional areas, and, calling for tenders, received, in May, 1882, offers from eight firms. In one tender only was the question raised of supplying light for private consumption.

(*b.*) Messrs. Siemens's offer to continue lighting No. 3 district at £3,600 a year, being an advance of £1,330 on their original contract, was declined, and that firm retired from the City.

(*c.*) An arrangement with the Brush Company to continue for another year lighting No. 3 district at a cost of £800 per annum was made.

But, as we all know, the Electric Lighting Act of 1882, which obtained the Royal consent and became law in that year, appeared, and with it a flood of applications for provisional orders and licenses, three of which covered the area of the City, and obliged the Commissioners to hold their hands and consider the position in which the Act placed them, after having already had the subject in hand for nearly four years.

In November, 1882, the Streets Committee of the Commissioners of Sewers consulted Mr. Preece, and I shall take this opportunity to remind him of a statement he then made, and has since repeated, on the subject, in which, I am happy to be able to say, he showed an accuracy of foresight in which later experience has fully supported him.

* It was estimated to cost over £8,000, but, through the inability of the contractors in No. 2 to commence lighting in time, and for other reasons, it actually cost about £5,400.

General Webber

At that date he wrote: "I know of no branch of engineering "where more forethought is necessary to calculate all the con-"tingencies likely to be met with than a system designed to "illuminate a large city like that of London."

Meantime, an experiment with public lighting by glow lamps had been in progress. In April, 1882, the Edison Company commenced an experiment with that means of illumination on the Holborn Viaduct for a length of 466 yards, upon which Colonel Haywood reported after a twelvemonth's run. Ninety-two 16-C.P. glow lamps replaced the gas burners in the existing street lanterns, 86 14-C.P. gas batswing burners being displaced. The result in light and cost was that the electric lighting contractors gave 1¼ times the light at the same price as gas—namely, £4 10s. 4d. per burner per annum.

That this experiment led to but negative results we all know. If it showed anything, it was that the substitution of a glow lamp in the ordinary street lantern for the lambent flame of a gas jet, so that the incandescent filament is directly visible, is a very poor and unintelligent application of the electric light, and puts it in a position in which it is at a great disadvantage in comparison with gas. I believe that the glow lamp for public lighting purposes never quite recovered from the results of that experiment.

The City was one of the earliest areas upon which the electric light manufacturing companies set their eyes. Hardly had the 1882 Act become law when, as I have said, three companies commenced applications for provisional orders. As still now occurs, the local authority took alarm, and began to investigate the subject for themselves. Most complete reports as to the law, engineering, and science of the question were made by Mr. Baylis, Colonel Haywood, and Mr. Preece. These gentlemen may be said to have been amongst the very first to compile information for a local authority on the subject of electric lighting; and, although ten years have passed, the terms they used, conclusions arrived at, and recommendations made, differ very little from those that have since, and up to this date, been, and are being, laid before similar governing bodies for their information and guidance.

The general tenor of the recommendations made in 1883, especially by Mr. Preece, were that the Commissioners ought to obtain their own provisional order or license, and, either by contractors or by their own officers, to carry out the undertaking for themselves, both for public or private supply. General Webber.

The consequence was that in March, 1883, the Commissioners decided to apply to the Board of Trade for the necessary license under the Act of 1882, for the whole City, having in its terms a compulsory area of a limited size, and to oppose all other applications for provisional orders and licenses under the Act of 1882.

Although tenders from a number of electric light manufacturing companies were called for and received, it is of moment to note that Mr. Preece reported that their terms were all "eminently "unsatisfactory."

No doubt his criticisms were correct, but, as the length of time of the proposed contract was limited to seven years, it is not surprising that they were not such as could be accepted. The lowest and highest offers for each public light arc lamp were £36 and £71 per annum respectively.

In spite of amendments in those proposals, Mr. Preece could still find nothing to recommend them; but we, who look back to what has transpired in the interval, can realise that all proposals made in those days, when the security offered was such that capital recoiled from it, were necessarily wild and unsatisfactory, and were mostly made by firms who, if they were sound, must have secretly hoped never to be called on to carry them out.

Meantime, the Anglo-American Brush contract for lighting, for about 4,030 hours per annum, New Bridge Street, Ludgate Hill, and St. Paul's Churchyard still ran on, and was costing the City at a rate of less than £25 a lamp.

Then, in 1883, commenced a period during which companies proposing to obtain statutory powers within the City were kept at arm's length, and during which, Mr. Preece, instructed by the Commissioners, made experiments on the subject of public lighting by arc and glow lamps, partly with the aid of the Brush and Edison contract installations then running.

In 1883 he reported "that, while the arc lamp is admirably

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"adapted for the illumination of large spaces, the glow lamp is "eminently adapted for our streets and narrow thoroughfares."

Mr. Preece's report to the Commissioners of Sewers, of August, 1884, while being very exhaustive as to the whole question of electricity supply generally, is certainly also the standard report on the subject of public lighting.

He then stated, however, that "the lamp which, in my "judgment, best lends itself to street lighting is the glow lamp, "and of the glow lamps I prefer the 50-candle lamp for the main "thoroughfare."

Notwithstanding the Holborn experiments, Mr. Preece recommended further trials of public lighting with glow lamps, combined with a means of distribution for private lighting within a small area that would require about 5,000 private lamps, at a cost to the City of about £40,000. He also brought very prominently to notice the very valuable proposals of Mr. Trotter connected with his dioptric lantern, to which I shall myself allude later on.

These further experiments were never carried out, but I think the meeting will be glad to hear from Mr. Preece if any modifications would now be admitted into his views, on a subject which the meeting is aware is not yet satisfactorily settled?

For more than a year the subject slept.* At that time it fell to my lot to be placed in engineering management of the Anglo-American Brush Electric Light Corporation, and since then, up to July, 1892, I was intimately acquainted with all that has gone on connected with the lighting of the City of London.†

The original contract of 1881 of that company for lighting New Bridge Street, Ludgate Hill, and St. Paul's Churchyard, with arc lamps, still ran; but there were many outward signs of considerable repairs being necessary in the mains.

These mains had been laid into the district under the roadways

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* In November, 1885, a well-known writer reported to the Commissioners: "At the present time there is a complete stagnation in electrical enterprise "in England, in such enterprise as would undertake the supply of electricity "upon a large scale for public and private purposes in towns."

† My own connection with the public lighting of the City of London dates back to the sixties, when I assisted the late Dr. Letheby, City Analyst, in a series of experiments connected with carburetting gas for street lamps.

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from the Brush Works in Belvedere Road, along Bankside, and over Blackfriars Bridge, and they consisted of two circuits of 7/16's drawn into the same cast-iron pipes, with insufficient draw-boxes and means of inspection; although the insulation was sound throughout the greater portion of their length, there were many points at which it had been attacked, by the pipes having been hastily laid where they were exposed to soil saturated by sewage liquids and other gases and with insufficient means of access for localisation and removal of faults.

The currents were generated by Brush arc dynamos, old-pattern armatures, having belt gearing, to engines, which, with the boilers, formed part of the power which was used in the Brush factory, on which the demands were irregular and occasionally very heavy. The fact was that the Brush Company, when they tendered for the work in 1881, understood it was to be an experiment, out of which little or no actual profit could be expected, and little thought that arrangements which would have been good enough for twelve months would be continued by the City authorities for five years, only terminating through the initiative of the Brush Company, and by the permission of the Commissioners, in December, 1885.

No public body has probably taken more pains than the Commissioners to weigh carefully the *pros* and *cons* bearing on the question of their becoming themselves the undertakers for supplying electricity;* and I think now, that, but for the host of offers, merely speculative and otherwise, which was being continually sent in to them and diverting their attention from the issues most in the interests of the ratepayers, they would in the end have decided on raising the necessary capital to do the work themselves.

In November, 1885, a set of proposals was formally made by the Brush Company to contract for the public and private supply of a district of the City, and this was considered by a committee, of which Mr. J. C. Bell was chairman.

This was the first practical arrangement on a large scale that

* So late as April, 1890, they deputed Mr. Preece to report to them on the electric lighting of the public streets of Taunton with arc and glow lamps.

General Webber] had ever come before the Commissioners, and its terms are almost *verbatim* those that were eventually adopted in January, 1889, as the conditions under which the Commissioners would receive tenders.

From that moment the question of the lighting the City made a fresh start on a tangible basis as to cost and mutual advantages; and, although it took five years to mature, there was no longer any serious question of the Commissioners themselves becoming the undertakers. In 1886, 1887, and 1888 the matter was again from time to time before them, and throughout that time it was due to the personal exertions of some enlightened members of the Streets Committee that the matter was kept continually to the front.*

One of the reasons for the delay was due to a great reluctance on the part of the Commissioners to permit any company to have a provisional order within its area of control.

The chief reason for this was the condition of things at and below the surface. The occupation of the subsoil by sewers and subways, by the systems of gas, water, and telegraphs, and by various other objects, is entirely exceptional. They would have much preferred that all powers for the disturbance of the surface should be conferred by themselves only, and not by statute.

There is no doubt that the ratepayers of the City would now be in quite as good a position if no provisional orders had been granted, and if only the contracts that were eventually entered into between the Commissioners on the one part, and the Brush Company and Messrs. Laing, Wharton, & Down on the other, were existent. Owing to more than the ordinary rights of user of the soil of thoroughfares and streets being vested in the City Corporation, statutory powers were not necessary to enable them to grant way-leave.†

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* Mr. Frank Green, Mr. J. C. Bell, Mr. Graham King, Mr. Bridgeman, Mr. Pannell, and others.

† There is ample experience to show that, if much of the Act of 1882 had been repealed, so far as the metropolis was concerned, as was more than once urged on the Board of Trade, this, and many geographical and other anomalies, which have kept up, and will for many years keep up, the price of electricity in London, might have been avoided.

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In February, 1888, the Commissioners called for a report giving a *resumé* of all that had been brought before them in the previous 10 years, and I must here say that it fully establishes the claim of the Brush Company that a large share of the credit for the eventual results was due to their persistence in holding the ground when all others had retired, and in keeping the subject always before the local authority in a manner and in terms which, by their moderation and practical sense, were bound in the long run to commend themselves to business people.

The object of this report was to show that the successful use of arc lamps for illuminating large spaces had asserted itself all over the civilised world.*

The advantage of having a contract with a company to supply current to public arc lamps at 3·1d. per unit, including trimming and carbons, instead of at 8d. exclusive of the same—the usual price in provisional orders—was dwelt on.

The unsatisfactory nature of the proposals made to the City by other parties was fully exposed. The great advantage to the City if the terms of the form of contract originally proposed by the Brush Company in 1885 were adopted, and the misrepresentations that suggested monopoly which had been made, were dispelled; and, it is a remarkable fact, that the then proposed charge of 1s. per unit for private lighting was not considered excessive in view of the circumstances of the probable demand for business premises in the City.

January, 1889, found the Commissioners, again and finally, roused to activity by the Electric Lighting Act of 1888 (due to the personal exertion of Lord Thurlow, the chairman of the Brush Company), and, the City having been divided into three districts for the purpose of the contracts, tenders were publicly called for; and it may here be remarked that the company which, during eight years, had done so much to keep the matter before the public, at that moment was in no better position in March,

* The successful lighting on a large scale by the Brush Company of the Colonial. Manchester, and Glasgow Exhibitions was described.

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1889, as regards tendering, than any other firm which was then only dealing with the matter for the first time.*

But yet another stage of opposition had to be got over before the final arrangements for this great undertaking could be said to be on a satisfactory footing.

Major Marindin, in April, 1889, had reported against the claim of the City to be exempted from the operation of the Electric Lighting Act, and had, in face of the opposition of the City, recommended the approval by the Board of Trade of the applications for provisional orders from two of the above-named companies.

The Brush Company had for several years, in deference to the views held by the City authorities, refrained from making applications for orders, and therefore their absence from the list of applicants in 1889 was intelligible.

In the terms of Mr. Preece's report on Major Marindin's contention, the City had been "regarded merely as a local Vestry "with some ancient rights that have to be respected;" and that "the amount of lighting and the capital necessary to be expended "in the City, which far exceeds that for any other portion of the "metropolis," had been overlooked. Major Marindin by his recommendation had neglected not only the geographical part of the question, but the fact that the Commissioners of Sewers had been for years studying and experimenting on the question of effective public street lighting.

The tenders for public lighting the main thoroughfares (see the streets shaded, Fig. 1) with arc lamps which eventually were reported on, in November, 1889, by Mr. Preece and Colonel Haywood, were—

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* The contractors who tendered were the—

1. Central—Anglo-American Brush Corporation.
2. London—London Electric Supply Corporation.
3. West—Metropolitan Electric Supply Company.
4. All—House-to-House Electric Supply Company.
5. East—Messrs. Laing, Wharton, & Down.

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The Metropolitan Electric Supply Co.'s revised tender to light the Western district with 121 lamps, at £26 ...	£3,146
The Anglo-American Brush, the Central district with 138 lamps, at £26 ...	3,588
The London Electric Supply Corporation, with 136 lamps (half the lamps being extinguished at midnight), at £24 2s....	3,290
Total for the main thoroughfares	£10,024

and the acceptance of these was recommended.

But of them the Brush Company alone (consistent with their original proposal) had not applied in 1889 for a provisional order, and had agreed to the division of profits under a sliding scale—namely, that if the profits exceeded a cumulative dividend of 10 per cent. per annum upon the capital invested, the excess was to be divided equally between the contractor and the consumer—and also had agreed that power should be reserved to the Commissioners to acquire the undertaking and works by purchase at the end of 21 years, in all other respects in accordance with section 2 of the Electric Lighting Act of 1888.

Meantime, no provisional orders had been granted for any part of the City area, owing to the withholding of the usual recommendations from the local authority which the Act requires.

But on the last day of June of that year the Brush, and the Laing, Wharton, & Down Companies gave notices for the Western and Central and the Eastern districts, respectively, and the ordinary statutory steps followed in due course. The Brush Company had, as stated, accepted the terms of the Commissioners' contract, and the Laing, Wharton, & Down Company now decided to fall into line with them;* and in May, 1890, those contracts

* The Commissioners had required Mr. Preece to report fully on the Thomson-Houston system of arc lighting as established at Sheffield and the St. Pancras Station, as well as at Taunton.

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were sealed, and the provisional orders became law in that session of Parliament.*

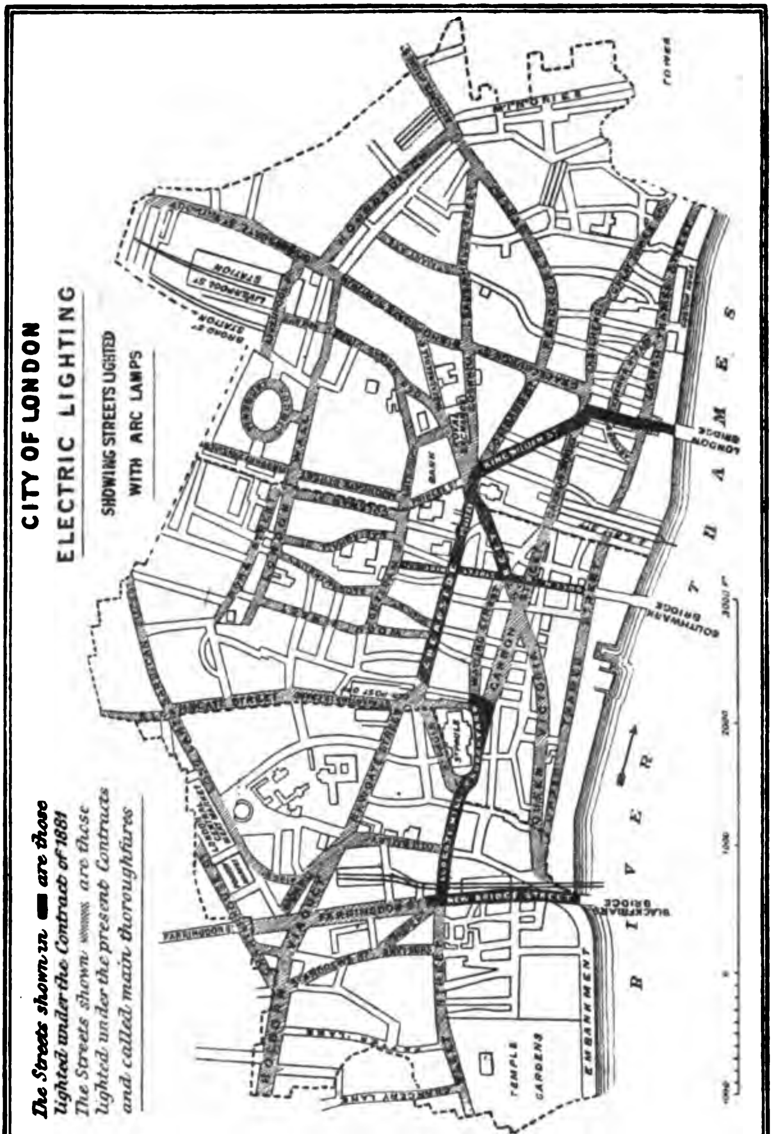

FIG. 1.—Map of all City, with main thoroughfares shaded.

* The names of Mr. E. Garcke (managing director of the Brush Company) and of Mr. Sydney Morse are so well known in connection with the industry, that it is appropriate to record here that to them is largely due the credit for carrying through final arrangements for these orders, which were exceptionally intricate in their character

Not until 1891 were a similar contract and provisional order granted to the Brush Company for the Western district. Thus, after nearly 13 years of deliberation on the subject, the scheme for supplying electricity to the City of London for public and private consumption became legally possible, and all the special powers which the Commissioners sought to obtain in the interests of their ratepayers had been secured. General Webber.

Capital Expenditure.

The question of raising capital for electricity supply companies has not differed much in its conditions from other sister industries.

This paper would be less instructive if that part of the subject was overlooked, and it is noteworthy that, even with a field for the supply of electricity in which the gas company had a gross income of over £370,000,* even in 1891 it was not thought prudent to do what is called "go to the public," in the first instance, with a plainly stated prospectus. Such a statement most certainly would have shown that the supply of electricity to the City should be an undertaking affording as sound an investment as could be found anywhere, and also one which at an early date, under the operation of the sliding scale already alluded to, would allow of the cost of the current being reduced below the maximum of 8d.

As we all know, a very old way of commencing to raise capital has been brought out under a new name, namely, by the starting of a "pioneer company," which is one way of getting an instalment of capital together to make a beginning.

Of course there is no engineering justification for it, but the financial physician has prescribed it, and hence this first capital must be spent with a primary object of showing that something can and will be done.

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* The day and night populations of the City, respectively 261,061 and 50,652 in 1881, had altered in 1891 to 301,384 and 37,694. The day population, as compared with counties and towns in England and Wales, is larger than 26 counties, and all other towns except Liverpool, Manchester, Birmingham, Leeds, and Sheffield. Before 1891, there were 3,136 public gas lamps, costing £10,530 per annum.

General Webber

The future of the undertaking from the structural point of view may become quite a secondary consideration, and, indeed, may be ignored if it interferes with the parade with which it is intended to "draw" the investing public. They—the public—have only themselves to thank if this sort of thing is necessary. Engineers and contractors have no real interest in its existence.

The contracts with the Commissioners for the public lighting of the City were dated—

For the Eastern district, 28th May, 1890;
" Central " 19th " "
" Western " 5th February, 1891;

and they required that the main thoroughfares should be completed with arc lamps in the Eastern and Central districts by the 28th and 19th February, 1892, respectively, and in the Western district by the 5th November, 1893.

The "first sod was cut" on the 5th January, 1891, when a junction box was constructed on the west side of the Mansion House, with an inscription inserted in the wall. The first street was lighted in July, 1891.

The arc lighting generating plant was permanently fixed in the pioneer buildings, but in other respects the installations were designed to be temporary.

The two companies—namely, the Brush Electrical Engineering Company, and the Laing, Wharton, & Down Construction Syndicate—to whom, as has been stated, the provisional orders and contracts had been granted, had in February, 1891, transferred their interests, through an exploration company and an electric and general investment company, conditionally, to the City of London Pioneer Company, of which company I was appointed the engineer after the contracts had been made. These interests included the obligation to complete the purchase of sites for generating stations—one at the Wool Quay, in Lower Thames Street, the other at Meredith's Wharf, in Bankside.

Part of the consideration for the transfer of the responsibilities and liabilities of the "*concessionaire*" companies was in each case a provisional contract for the supply and erection of the entire plant and equipment of one temporary

(or pioneer) and one permanent generating station for the supply of current to, and for the transforming of current in, each district. General Webber.

In similar cases the work of pioneer companies has been confined to the task of financing. Unfortunately—I think—in this case the City of London Pioneer Company had to undertake actual work, so far as the public lighting was concerned, because the time remaining—namely, about 12 months—in February, 1891, when the contracts for the Central and Eastern districts had to be completed, was even then very short.

But these provisional contracts for temporary work included some private lighting;* the object being the old-fashioned one, to create a display—in my opinion—at the expense of good work, and with the risk of a legacy of trouble, anxiety, and failure.

Suffice it to say that, in spite of every possible precaution to prevent it, no small part of this temporary work has had, or will have, to be moved or altered after having been put to work; and a large part of the money spent on these temporary installations—amounting, together with other expenses, to a very considerable sum—must be more or less wasted.†

On the 13th July, 1891, while the pioneer contracts were still uncompleted, all the interests acquired by the pioneer company were taken over by the City of London Electric Light Company for a further consideration, by which means the lighting of the

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* The first current for private lighting was commenced on the 11th December, 1891. to the Mansion House, but it was more than six months after before the plant could be run during daylight hours.

† I had been through such troubles in connection with electrical and other engineering too often not to throw all my weight into the scale against temporary work of any kind.

It is only before an assembly of engineers that an engineer can hope to find any appreciation of such a situation. Neither financiers nor contractors sympathise with his efforts to prevent unnecessary expenditure, except so far as it affects their own interests. The financier does not mind so long as the total expenditure is within his estimates of what the investor will stand; and the contractor need only care if he is going to accept any payment in shares, and not always then.

Besides this, there is the long series of harassing engineering consequences arising out of crude, hasty, and ill-considered work preliminary to a great undertaking. Many of us have been through it, and learnt to take it as part of the day's work; but, all the same, it is always regrettable.

General Webber.

City was, with the consent of the Board of Trade and of the City authorities, amalgamated into one undertaking instead of three, and it was at last possible to begin work in earnest, with a hope that the words "temporary" and "provisional" were past.

The estimates for works upon which the capital of the new company was raised amounted to—

Buildings	£53,000
Equipment of the three stations ...	493,250
Distribution	342,850
Total	£889,100

This was exclusive of the cost of the sites.

The contracts for public lighting with the "*concessionaire*" companies which had been taken over from the pioneer company, besides providing for the supply and installation of the plant and equipment for one station for each district of the City, also provided the arc and glow lamps for the public lighting, with their fittings (exclusive of posts and lanterns) in every respect sufficient to enable the new City company to fulfil the terms of the contracts with the Commissioners of Sewers, as follows:—

Eastern District.		Central District.		Western District.	
(Laing, Wharton, & Down Co.)		(Brush Electrical Engineering Co.)			
Arc.	Glow.	Arc.	Glow.	Arc.	Glow.
233	307	138	302	144	297

Total arc, 515. Total glow, 906.

Besides this, the contracts between the same parties required the work to be done for equipping the stations and providing the plant for the supply and conversion of current for private lighting to be in accordance with detailed specifications and schedules of prices. It was agreed that these details and prices were to be laid down afterwards and settled between the engineers of the company and the contractors; differences (if any) to be referred to Mr. Preece.

The contracts required that the output of the Brush stations for the supply of the Central and Western districts, and of the Laing, Wharton, & Down Company's station for the Eastern district, should, including the pioneer plant, be as follows:—

General Webber.

	Public and other Arc Lighting. Kilowatts.		Private Lighting. Kilowatts.
Eastern district	450	...	4,800
Central „	330	...	3,900
Western „	220	...	3,400
	1,000	...	12,100
			1,000
Total kilowatts	...	..	13,100

Adding together the cost of the contracts and estimates, and dividing by the total of 13,100, we obtain the following total cost per kilowatt:—

Preliminary expenses	£8,000
Work done by the pioneer company, including some work of distribution	46,000
Extras on ditto	10,000
Contracts for the stations	493,250
Estimate of cost of completing distribution ...	342,850
	900,100
Add 8 per cent. for the cost of the sites of the generating stations	72,008
Total	£972,108

Namely, total per kilowatt, nearly £75.

Anyone present will realise that the preparation of detailed specifications for the equipment of an electric light supply station, both for generating and transforming, requires the fullest technical description. Besides that of the boilers, engines,* and

* Professor S. P. Thompson's opinion, in November, 1891, on the types of engines which the contractors, under the restrictions and definitions contained in the specification, proposed to adopt, was that, while expressing his own opinion on the advantages of triple expansion, and of engines of the closed type, he confirmed entirely the conditions that the choice should be of the vertical and direct-coupled type; he postponed his final opinion until six months' running of the first group of 400 kilowatt units had been completed. It is to be hoped that he will be able now, more than two years having passed, to give electrical engineers his further experience in the subject.

General Webber.

dynamos, there are the questions of the arrangements for transport and conveyance of coal and refuse, economising, condensing, and stoking; there are also the details of foundations, drains, subways, travellers, lifts, cranes, and the lighting of the station, as well as telephonic communication with, and equipment of, transforming sub-stations.

I need not say that the preparation and agreement as to the details of specifications, after a contract is made and the total price to be paid is fixed, is a somewhat novel task for the engineer of the spending company.

In this case the putting of the cart (as it were) before the horse fortunately did not end in miscarriage. The engineers on both sides* were anxious, while doing justice to their employers, to arrive at a fair and reasonable solution, and Mr. Preece could tell you that it ended in only about half a dozen points of difference between them and me having to be referred to him, in specifications containing nearly 120 pages of closely printed matter.

In these specifications, although the specialities of the two contracting firms were well known, nothing was laid down to confine them to their own particular make of engines, boilers, dynamos, transformers, and lamps.

The contractors described to me the sizes of the units they desired to employ. They are not limited to any particular form of driving, and, as far as possible to produce uniformity, the speeds and electrical conditions which they desire to use are allowed.

Economising, automatic stoking, and condensing, and all possible accessories—including testing and switch-room apparatus and fittings—are required of capacity equal to the full output of the plant.

All the conditions of the different stages of generating are rigorously prescribed so far as the results under test are concerned. For instance, it is laid down in the specifications

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* Mr. Raworth, and Professor Kennedy assisted by Mr. Wharton, represented the two contracting companies, while I represented the City of London Electric Lighting Co.

General Webber.

that, after providing for all extraneous steam consumption and waste, the standard of consumption of coal, including the steam used in the condensing pumps, shall not exceed 5 lbs. for the high-tension alternating currents, and 7 lbs. for the high-tension continuous currents, per Board of Trade unit delivered at the terminals of the primary mains in the stations. Amongst the extraneous uses of steam to be excluded from the above basis are included that used for the power expended in moving water, coal, and refuse.

The tests to prove this are adapted to the circumstances of running the station*—a matter, as most of us know, not always easy. Therefore their nature and number are to be subject to the approval of the engineer, so as not to clash with the conditions of statutory supply from the station.

The tests of each unit estimated to have an output of 400 kilowatts, or of each group of units with an output of 1,200 kilowatts, are necessarily dependent on the circumstances of the load on the station.

The alternating plant—both Brush and Thomson-Houston—was experimental at the time the contracts were made, therefore the first examples had to be under trial for six months. These trials had to be coincident with the supply, and dependent on the load on the station, and the contractors for that period were to be responsible for failure of all kinds.

Under strict penalties, the contractors are answerable for the dimensions of foundations, flues, and chimneys, and are required to guarantee absence of vibration, noise, and smoke nuisance.

As regards the boiler tests, under the usual conditions of temperature, external and at the base of the chimney, and state of barometer, and with coal having a calorific value of 13,500, it is obligatory that 77 per cent. of the heat is transferred to the water by the boilers and economisers together.

As regards the consumption per H.P. of steam in the engines,

* The contractors could not provide means of running their large dynamos at their works. All real tests had to be made after delivery. This was an inherent difficulty for the engineer.

General Webber.

the Brush Company have agreed to a limit with full load of 22 lbs. of steam exhausting to the atmosphere, and 18 lbs. when condensing. The Laing, Wharton, & Down Company have agreed to a limit of 20 and 17 respectively.

For the commercial efficiency of the electrical 400-kilowatt generators, 80 per cent. when working at full load is prescribed, 2 per cent. of that only being allowed to be absorbed in the excitation.

Besides, there was given a description of every test which each portion of the plant would be required to sustain. At the same time the widest latitude as regards *design*, throughout the whole of the station plant and accessories, is allowed.*

I do not know if the meeting considers if any better way could be adopted for protecting the expenditure of capital and stimulating the energies of contractors, after it had been decided by others how much should be spent, how much should be the maximum output of the plant, and who were to be the contractors.

What was probably one of the most difficult parts of the task was the description of the details of the adaptation of portions of the plant to sites and buildings still under design, so that no extras on the contracts should arise, and thus the equipment of the stations and sub-stations should be of the most complete and up-to-date description, and fully equal to the requirement of the capacity which the contractors had undertaken to provide.

Both sites presented exceptional features, and the designing of the building structures for each differed entirely.

That for the Wool Quay (since abandoned)† required a building in which the floor of the basement would have been 20 feet below high-water mark, and the station plant would be placed on floors one above the other; the generators to be in the basement, the boilers over (on a Hobson's steel girder floor), and the coal above.

The site at Meredith's Wharf, although the essential features

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* The essence of these specifications was that, except in respect to a few points not within the scope of the contractors' work as electrical engineers, all details of design were left to them, subject to the final approval of the engineer.

† This site had to be taken over by the City company under the "*conces-*"*sionaire*" contracts.

of the first design have been retained, has been so enlarged that any description of it that might be attempted in this paper would not be sufficient.* General Webber.

The estimate of the load-factors of the *public* lighting of the City may be here made with some interest.

Adopting Mr. Crompton's figure, which allows 25 per cent. for extra or reserve machinery, in the case of the public lighting the capacity of the plant is 890 − 222 = 668 kilowatts, or 5,851,680 kilowatts per annum. The 515 arc lamps represent 257,500 watt-hours, and the 906 glow lamps—half being 100 watts, and half 50—represent 67,950 watts more, or a total hourly consumption of 325·45 kilowatt-hours, which, with 4,030 running hours in the year, gives a load of 1,311,562 units per annum.

But, in fact, the amount of the above plant that is spare, or available for arc lighting in public buildings and elsewhere, is very large, and it is better to regard the actual capacity of the plant exclusively devoted to public lighting, including reserve, as represented by sixteen ·50 (500-watt) light machines, with an annual total capacity of 3,504,000 kilowatts. This will give a load-factor of 37·4.

DISTRIBUTION.

Outside the Postal Telegraph and the City engineer's offices there was no one who could form any accurate idea of the condition of things below the surface of the City streets.

The subways in Victoria Street, in Arthur Street, and in the

* The Institution will be better served if I leave it to the gentlemen who were selected by me as my assistants for that part of the work, and who have actually since carried it out—namely, Colonel Seddon (late R.E.), and Mr. C. Thompson. The meeting will, I hope, understand that in refraining to give any detailed description of the equipment of the stations I am influenced by the wish that such should be undertaken either by the engineers of the respective contractors who designed and erected them, or by Mr. J. H. Jackson (one of my assistants), who is still superintending the same. As regards the building structures, I may, however, add that of three chimneys designed, and specified and contracted for under me, one—*i.e.*, that now to be seen close to Bankside—has been erected. There are features of its construction, especially with reference to the bond, that I should like to have time to describe. Its cost was £2,075, its height 150 feet, and its internal diameter 12 feet.

General Webber

Holborn Viaduct, although suitable for through mains of supply of any kind, were eminently not so for electric distribution conductors, which have to be tapped at frequent intervals for the supply of current for public and private lighting. Although forced to use them, the cost of such mains and services to a supply company is higher than if the lines were laid under the footway on either side.*

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* In March, 1890, the London County Council, with the approval of the Board of Trade, and the confirmation of the Home Secretary, under the terms of the Metropolitan Subways and Government Acts of 1868 and 1888, had published bye-laws for regulating the use of subways. These, while in force in the Queen Victoria Street subway, are not so in those under the Holborn Viaduct and Arthur Street.

Anyone who has used street subways for electrical conductors, in common with gas, water, and other companies, will understand that, except for primaries, the electrical engineer would much rather remain outside.

The bye-laws are excellent for the regulation of this user, but the panacea which excellently-intentioned persons believe exists in street subways falls short of theirs and the public's expectations.

The law allows the local authority to oblige us to use them where they exist, and to charge us a rental for that use; but, as the word "pipe" in the Act includes a "tube for wires," and as the rental, irrespective of the number of wires, is £16 per annum for a 3-inch pipe for the 1,200 yards of the Queen Victoria Street subway, and £49 per annum for one under 18 inches diameter for the same length, the way-leave is not very costly, but the cost of using it is extremely so.

Sections of some of the subways, with the conduits placed in each for electric light conductors, are shown.

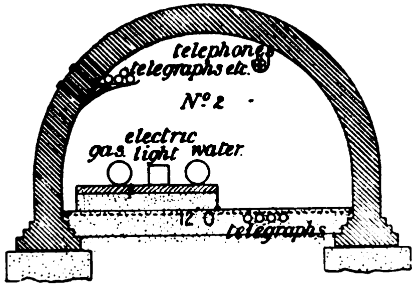

FIG. 2.—Holborn Viaduct Subway.

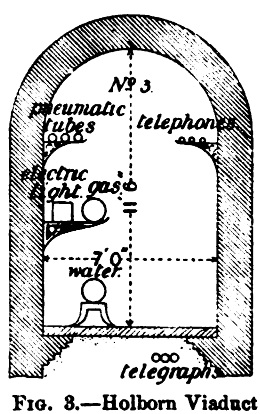

FIG. 3.—Holborn Viaduct Narrow Subway.

In every case, the obligation to use the subway instead of the ground under the footways entailed excessive expenditure—namely, on works in breaking

My own Postal Telegraph experience in 1871 and 1872 had been in the difficult ground in thoroughfares like Cornhill; and although in 1891 and 1892 places were come upon where hardly a single conduit could be laid, the task, owing to the system adopted, proved, on the whole, less difficult than was anticipated; and, as was expected, generally, the thoroughfares running north and south were easier than those east and west, for the reason that most water, gas, and telegraph, mains, tend from the City towards outside centres in the latter directions. General Webber.

The pioneer work included the opening of certain main thoroughfares, so that the arc lighting might be got forward.

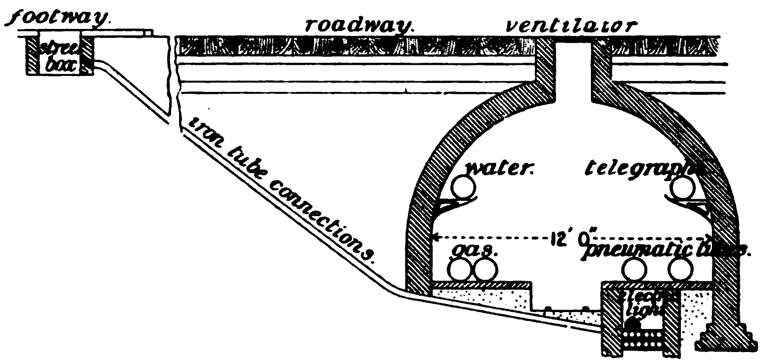

FIG. 4.—Subway, Charterhouse Square, with Street Box.

through the massive arches, and deep cuttings in the roadways, to get at the street lamps, and, in many places, to obtain access to the houses, in some places 30 feet away.

In the Arthur Street and Holborn Viaduct subways a large number of "ways" in Callender-Webber casing have been secured at a very little cost.

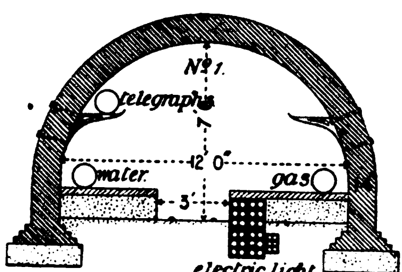

FIG. 5.—Subway, Arthur Street.

General Webber.

In these, the most thronged streets of the City, it was essential not to have to repeat the inconvenience of opening the ground. Whatever was laid down at the first operation had to form a portion of, and suffice for, the completed scheme.

In a matter so long under my own consideration I had no hesitation in recommending that sufficient conduit accommodation should be provided, and that it should take the following form, viz.:—†

(*a.*) Iron pipes for concentric high-tension mains from the generating to the transforming stations.

In the Queen Victoria Street subway, cast-iron troughing on wall brackets, as first designed, proved an awkward and costly arrangement in many ways; the weight of the structure was nearly 3 cwt. per yard.

Lighter troughing designed by me was adopted, of which follow sections.

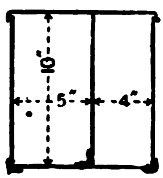

FIG. 6.—Section Square Trough.

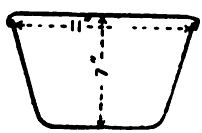

FIG. 7.—Section Rolled-Iron Trough.

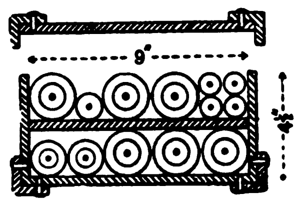

FIG. 8.—Section Trough with Cables in it.

The trough (Fig. 8) contains cables—six of 1·9″ external diameter, three of 1·5″ external diameter, and four of 0·7″ external diameter; with a carrying capacity in section of copper available at 2,000 volts = 0·09″, at 200 volts = 2·1″. Weight of trough per yard = 90 lbs.; cost of trough, fixed, 16s. per yard—with conductors, high-insulation bitumen, £4 2s. per yard run.

The essential objections to working in such subways (apart from maintenance) are—(1) The difficulties, physical and otherwise, of access to them, both for *personnel*, material, and plant; (2) the delays to work, due (*a*) to defective lighting, (*b*) time required to communicate with the authority and other occupiers, (*c*) to foul atmosphere; (3) the engineering obstacles due to the works of previous occupiers, and to the cutting in and out where necessary to reach side streets.

† The entire responsibility of thus advising the pioneer company rests with me. As the pioneer contracts (with the making of which I had nothing to do) had only provided conduits sufficient for the cables from the pioneer generating stations, and had specified nothing as regards the underground conditions, it was necessary, in order to prevent the consequent waste of having to excavate the same ground twice, to make additional provision. And as the isolated areas treated by these pioneer contracts had to be considered as forming a part of the great whole, all the details of the completed work had to be gone into.

(*b.*) Iron pipes for continuous-current high-tension mains for the public arc lighting. General Webber.

(*c.*) Bitumen concrete casing for three ways, to accommodate the conductors of a low-tension distributing system, both feeders and distributors.

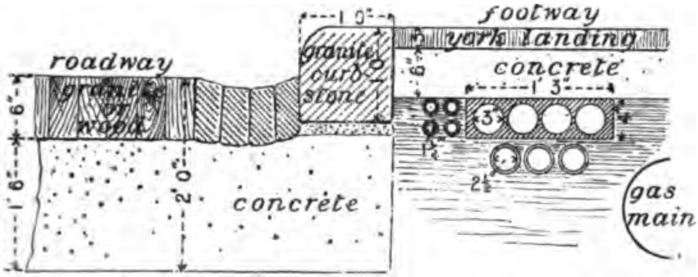

FIG. 9.—Sections of Road.

The future needs of the great whole had, as I shall describe further on, to be thought out before March of 1891, so that each part of the work, however preliminary, should eventually fit in to the permanent system.

The future need for spare conduits, possibly for telephones, had also to be thought of, and it was provided for as far as the very limited space under the footways of those thoroughfares which were first treated would permit.

The question of interference, through the neighbourhood of alternating-current working, with telegraph and telephone circuits was at that time under public discussion.

I had very little time, and had to be satisfied with one experiment having the object of observing the screening effect which was anticipated would exist through the interposition of what might be called "faggots" of iron pipes, lying in the same trench as the non-conducting conduits, into which the low-tension distributing mains were to be drawn.

For the experiment, conduits and pipes were laid on trestles under nearly the same conditions as in the trench, and a 200-volt current with 100 frequency (obtained by transformation) and 100 amperes was passed through two of the three ways of a bitumen concrete conduit, in conductors having a sectional area

General Webber

of copper of about one-tenth of an inch. Telephone circuits with metallic* returns laid parallel were tried. The iron tubes were placed at various distances and in various numbers.

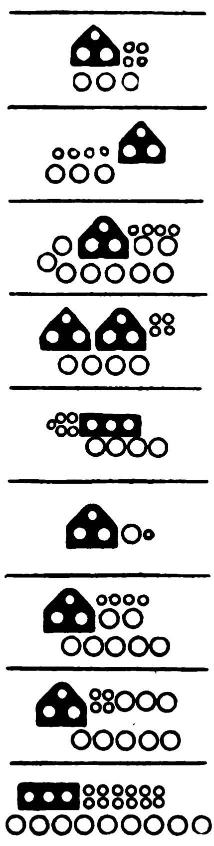

FIG. 10.—Various Typical Examples of Sections of Conduits.

Imperfect as the trial was, it gave us security that at a distance of 12 inches from the Callender-Webber casing, twin telephone circuits in iron pipes would be fairly secure from trouble. But, as an additional precaution, it was decided to sheath the casing with iron. Within a distance of about 6 inches a very slight disturbance could be still heard. A sample of casing thus treated is on the table amongst the other samples illustrated.

The choice was further justified, because the Duke of Marlborough, with his usual foresight, asked several practical engineers to meet him in a friendly way soon after this advice had been given and adopted, in order to discuss the whole question.

From my notes of that meeting, held on the 23rd and 24th March, 1891, I find the conclusions then come to coincided with the system above referred to, which was already in course of execution.†

The following recommendations were formulated, with general concurrence :—

(1.) That a separate way should be provided for each separate conductor, for the purpose of drawing in and out between flush-boxes.

* Experiments made in 1880 with telephone circuits with and without earth returns, between Paddington and Westbourne Stations, laid in the same wooden troughs as 40 or 50 working single- and double-current telegraph circuits, saved me from having to make any trial with earth return for the telephones.

† Those present at this meeting were—The Duke of Marlborough; Messrs. T. Callender, Gordon, Gray, Heaviside, Mavor, Raworth, A. Siemens, Wharton, and Major-General Webber. It is not to be assumed that unanimity on matters of detail was expected or arrived at. As regards anticipated electrical troubles, the

(2.) That the high-tension primary alternating currents should have concentric conductors with vulcanised rubber dielectric, and be drawn into iron ways. General Webber.

(3.) That the arc lighting continuous-current conductors should be concentric, and drawn into an iron way, except in the lengths where the circuit is connected with lamps, when the 7/16 conductors should be separate, so as to avoid joints.

In connection with the secondary distributing conductors, the use of the three-wire system having been admitted, various means of laying were examined—such as large iron pipes, with and without interior separate ways for the cable; the use of paper tubes in iron cases; iron tubes lined with bitumen; and earthenware cases, with ways similar to the Callender-Webber bitumen concrete cases.

After carefully considering the conditions of the City streets, and all the circumstances of difficulty that were being met with and known to exist, the use of bitumen concrete cases with separate ways; and, in view of the experience and evidence of its efficiency, the use of Callender's bitumen insulation for the secondary distributors, met with approval.

After hearing all that was to be said as to the conditions for providing drawing-in and joint boxes in the City streets, no doubt remained as to the necessity for using a common box in most situations for all main circuits and their joints, and of making them as large as the space below the surface would permit.

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avoidance of interruption of telegraph and telephone circuits was the only thing dealt with at those consultations.

Those present had till then had, I must presume, no practical experience of the resistances due to skin effect, or self-induction, in the case of single conductors of over one-third of an inch section of copper used to convey alternating currents at *low* pressure.

The use of concentric lead-covered cables laid in the earth, with iron split-tube protection where joints have to be made, was discussed with the advocates of that system as used in Germany, and its advantages, both as to reliability, manageability, and first cost, in comparison with two or more highly insulated conductors in one iron pipe, were weighed, especially in view of the claim that, wherever laid, it is everlasting.

The question of influence on telegraphs and telephones, and the means of screening or damping down the magnetic field, was discussed, and various experiences at Bath, Newcastle, and in London were quoted.

General Webber.

The justification of the adoption of these resolutions was, both from the engineering and financial point of view, as follows:—

The use of footways wherever possible had been prescribed by the Commissioners. In spite of having to keep 6 inches under the lower side of the paving-stones, it entailed less labour in excavating.

At the place, where they had to be necessarily carried under the roadways, the conduits had to be laid below paving and concrete sometimes 2 feet in thickness. With a surface subject to the City traffic the numerous draw, service, and other, flush boxes, would have been impossible.*

The space available below the surface was occasionally entirely occupied by cellars, areas, and other pipes, and the work had to be carried out in the presence of officials representing—

1. The Commissioners of Sewers.
2. The Postmaster-General.
3. The Gas Light Company.
4. The Water Company.
5. The Hydraulic Main Company.
6. The District Surveyor.

The condition, exacted rigorously—namely, that no pipe or conduit should be placed vertically over or within 6 inches horizontally of an existing pipe—was a most arduous one to fulfil.

My procedure in the most difficult streets was as follows:—

Having decided on the maximum number of "ways" that should, and (if possible) be, laid under the footway, I began by examining it personally, having first obtained from the authorities I have named all possible information as to their pipes—information that was sometimes very imperfect. I then measured

* The following figures give an idea of the traffic in the City:—By bridges, streets, railway stations, landing piers, and subways there are 81 means of public access. By these the *daily* traffic was—

		1881.	1891.
Vehicular—	During 16 hours ...	66,909	85,286
	During 8 hours ...	4,984	6,546
Pedestrian—	During 16 hours ...	739,640	1,100,636
	During 8 hours ...	57,923	85,458

carefully all cellars, arches, and areas, and had trial holes opened wherever exceptional difficulty was anticipated. In many cases, such as in King William Street, so contracted was the space that several ways which were actually necessary had to be omitted and taken another way, and occasionally a deviation under the roadway was obligatory. General Webber.

The intricacies of the trench opened under such conditions could not, I believe, have been followed with any other system of ways—namely, the combination of Callender-Webber casings and wrought-iron tubes. Both these are capable of being bent on the ground to any reasonable curve—in the case of the iron pipes by the ordinary means, and in the case of the bitumen concrete cases either by warming the case and bending it when soft, or by laying short lengths and setting them at an angle to one another with mitred ends; the length of the short pieces and the angle of the mitres being, of course, dependent on the radius of the segment of the curve that has to be followed.

The difficult problem that faced the company in August, 1891, was the obligation to lay down their mains and complete the public lighting in all or parts of 53 streets by February, 1892, requiring approximately 17 miles of trench; and that the Commissioners were likely to be very stiff as to punctuality.

A careful consideration of the case in its various aspects had led me, when acting (up to and before 1890) as technical adviser to the Brush Company, to regard the adoption of alternating currents, delivered at high pressure and distributed at low pressure, as the service most suitable for private lighting in the City.

There was no hesitation on the part of all concerned to adopt it, particularly as in the case of the contractors the Mordey and Thomson-Houston systems had in 1890 reached considerable perfection.

The conditions which emphasised this view in my mind were geographical and local as regards the City. Whatever may have been the ultimate practice, they were paramount during the preliminary stage. They were, first, on account of cost of ground, that the generating stations should be at a distance; second, on

General Webber.

account of the exceptional difficulties in the streets for laying mains, the desirable frequency of converting stations might be impossible to achieve.

When the concessionaires (*i.e.*, the contractors) had the matter in their own hands, the sites already named for the generating stations were secured in, or in close proximity to, the City. Although this was a reversal of conditions, the selections were probably wisely influenced by question of facilities for sea-borne coal and condensing water, and largely controlled by the difficulty created by the Electric Light Acts in getting way-leaves through the areas of neighbouring local authorities.*

The facility, or otherwise, of obtaining sites for transforming stations could not be fully gauged during the preliminary stage, and space underground to be found for large conductors could only be expected to a very limited degree. If we had only known as much as experience has since shown, it is quite possible that a continuous-current system of distribution would have had as good a chance of being adopted as the alternating system.

Distribution with low pressure from transforming stations entailed a network on the well-known lines, with distributing service mains and feeders. When the time arrived for the City to be divided into areas, each to be served by a transforming station, with all the stations, if not the areas, intercommunicating, the areas and points for the stations had to be approximately assumed, and the number of ways estimated that would be required under each footway throughout the whole City. It would have been, of course, easier to have first found sites for the sub-stations and then arranged the areas to be served by them; but, as the main thoroughfares traversed the City throughout in all directions, there was no area that was not touched by the work requiring immediate completion, so that, to be able to get the above-named 17 miles done, all had to be considered in advance.

* For instance, negotiations extending over three years, with that object only, that I had conducted for the Brush Company with some local authorities on the Surrey side, ended only in obliging the company to seek and obtain a provisional order for the St. Saviour's district.

The combination of casings with 1¼-inch and 2¼-inch pipes (see samples exhibited) required a minimum sectional area of trench **General Webber.**

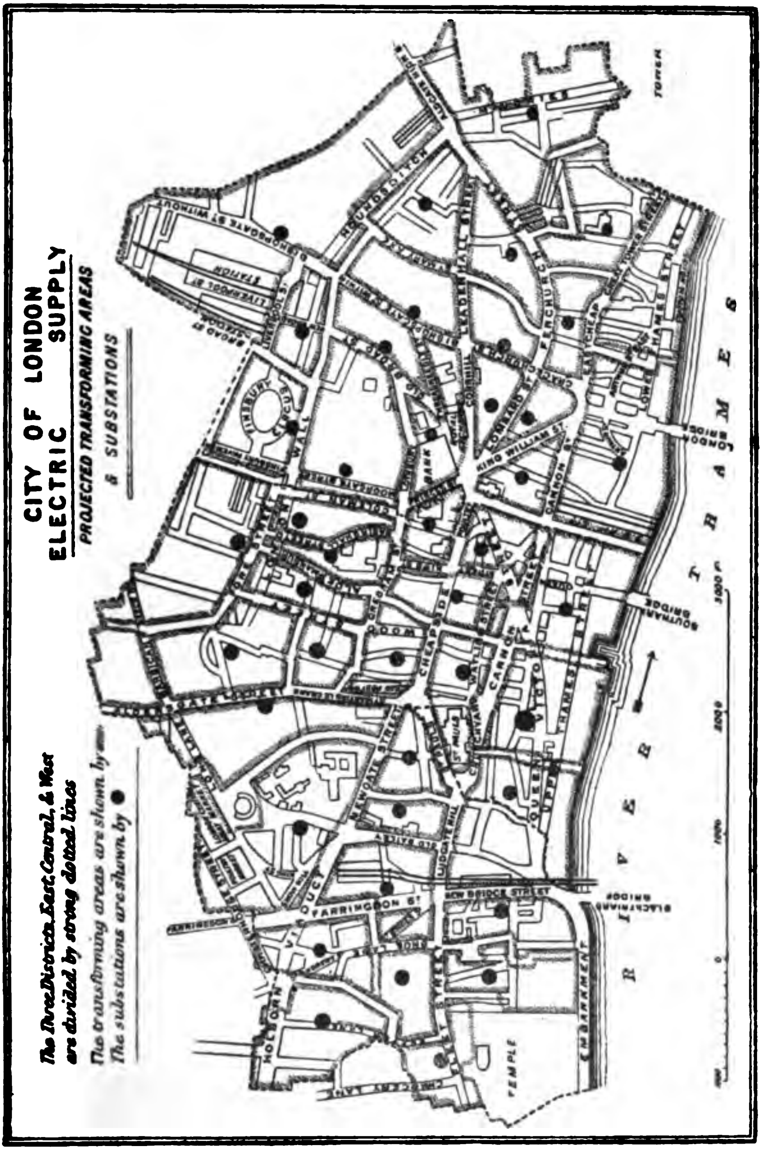


Fig. 11.—Map whole City, showing Points Transforming.

varying according to locality, and if the soil below the footways had been comparatively free there would have been little difficulty

General Webber. in arranging the position of the ways relatively to one another, so as to suit all requirements.

It was essential—

(*a.*) To place them so that the relative positions of the ends should coincide at any rate between box and box, no matter what might be their vagaries in the interval.

(*b.*) That, where the trench was opened alongside of a line of pipes enclosing telegraph conductors, the mass of the iron pipes should be laid between the alternating low-pressure conductors and the same, to aid in screening the inductive effect on the smaller currents.

(*c.*) That the ways destined to be used for the arc lighting, and for the distribution in the street itself, should be nearest the surface. As it was, the fulfilment of these and all other conditions I have mentioned was often absolutely impossible.

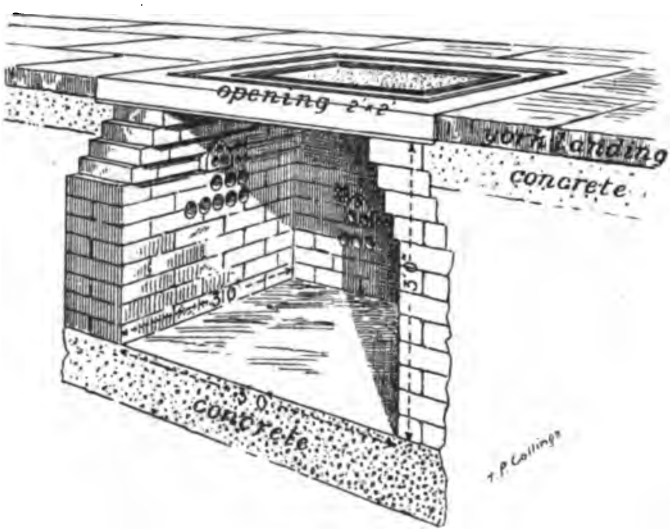


FIG. 12.—Example, Street Box.

The obligatory positions of boxes for drawing in and out and for access to the cables (exclusive of house service and street lamp boxes, which were only for access to the cables required) were numerous, as it was necessary to place one at every street corner, and wherever a serious change of direction occurred. Still, the

lineal space of line of main occupied by boxes was, on an average, only about 2 yards in every 100. These boxes were made as large as possible, which is not saying much; I aimed at making them large and deep enough for a man to get entirely inside, but this was rarely possible. Owing to the obstruction underground, they are of every conceivable size and shape. General Webber.

Drainage, and access of gas from the surrounding soil, are conflicting conditions. The drainage had to give way unless some nearer outlet was evident, and the boxes were made as gas-tight as cement and glazed or impervious bricks could make them.

This question of the presence of explosive mixtures in street boxes has, as my audience knows, been several times brought to notice by explosions—one lately in the Western district, on Ludgate Hill. My own view of this particular condition of danger has been to do everything to prevent the coal gas getting into a box, and I believe this can be secured with proper precautions, apart from the occasional possibility of being able to ventilate by in-draught and out-draught ducts.

The precautions are—(*a*) Good joints between case and case, ensured by finally passing the red-hot "mouse" through each joint after the casing has been laid; (*b*) absence of air space between the cases and the iron sheathing; (*c*) careful sealing-in round the iron tubes and bitumen cases where they pass through the wall of a box; (*d*) careful plugging of all "ways" not in use, and caulking with tarred yarn round the cables where they emerge from the "ways;" (*e*) the use of drainage only where the pipes are sure not to become ducts for gas; (*f*) ordinary care in the use of lights until gas is clear.

The nature of the material in, and shape of, the frames of the iron covers were the outcome of some experience. Nothing is better than a wide rim to the frame, roughed to prevent slipping, filled in with fine Portland cement concrete, made with very hard material, and allowed some weeks to set. The bad ones—and I see there are some—were the result of want of care and bad material. The wide rim provides space for letters indicating the ownership of the box.

In the trenches opened for that purpose all the conduits for

General Webber

conductors, the need for which in the future could be foreseen, had to be provided—

(*a.*) For the public lighting high-pressure conductors, concentric in some lengths, separate in others. (See samples of 1¼-inch pipes.)

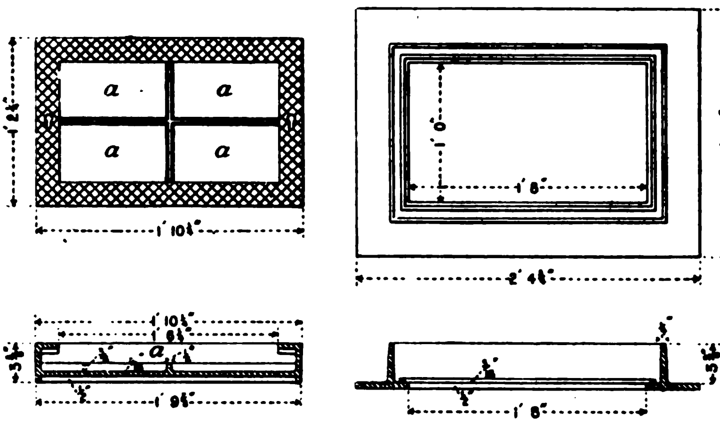


Fig. 13.—Example, Cover to Street Box.

(*b.*) For the private lighting primary high-pressure concentric conductors from the central to the converting stations, and between the latter. (See samples of 2½-inch pipes).

(*c.*) For the three-wire feeding mains to points in the network. (See various sections of casing.)

(*d.*) For the three-wire distributing low-pressure conductors of the network. (See various sections of casing.)

(*e.*) For the pilot or signal wires for the service of the company—one in each trench.

(*f.*) For spares and the future use of telephone conductors—as many in some places as 23—as the probable future demand indicated.*

As an under-estimate of the number and size of these meant a waste later on, in having again to open the streets, and as an over-estimate would be also wasteful, it was imperative, as I have said, to make a careful study of the whole.

* On this subject, from the point of view of the telephone service of London. I hope to be permitted to read a paper before the Institute at a future date.

General Webber.

This was done with an accuracy only diminished by the following:—

(*a*.) The number of existing lights that might be expected within a given number of years to be replaced by glow lamps.

(*b*.) The selection of the boundaries of the areas, and approximately of the points for the transforming stations.

(*c*.) The desirability, though not an essential, of arranging the areas so that the difference between the consumption in each should not be too great.

To the difficulties in finding sites for stations, and to the unforeseen obstructions to be encountered underground generally, all these became subordinate.

Careful canvassing of the City in various typical blocks of buildings (a "block" meaning all buildings situated between the nearest streets which meet one another) showed that they might be roughly classified in three, and that the number of existing lights, or lamps, averaged as follows, per square yard of ground space, was—

	Central.	Eastern.	Western.
First-class blocks, per sq. yd....	0·254	0·275	About the
Second-class „ „ ...	0·171	0·171	same as the
Third-class „ „ ...	0·067	0·100	Central.

Another canvass led to the conclusion that the proportion of those existing lamps that might be expected to be replaced by glow lamps was—

In the first-class blocks	0·75
„ second-class...	0·50
„ third-class	0·33

The above figures were applied, and, the blocks being all classified, and grouped in areas, so that each area might, as has been stated, have approximately the same number of lamps, the following results were obtained; and, although it will be a very long time before its general accuracy can be tested, I feel sure that, so far as the number of lamps is concerned, it is not very far from the truth, although the number of areas may vary very much from the estimate.

For the three districts the following figures were arrived at:—

General Webber

GLOW LAMPS.

	Eastern.	Central.	Western.	Total.
18 areas... ...	139,900	—	—	—
14 „	—	100,750	—	—
12 „	—	—	99,547	—
Total, 44 areas	—	—	—	340,197

If these are 8-C.P. lamps of 33 watts, this will give a load at the lamp terminals of 11,226·5 kilowatts. With 96 per cent. in the transformers at full load (the efficiency specified under the contract), and 5 per cent. loss in the mains, primary and secondary,* the output of alternating current of the three stations —namely, 12,100 kilowatts—is not far short of 12,236 demand the maximum possible load, so that with 80 per cent. of the lamps alight there would be nearly 20 per cent. spare generating plant.

If it may be assumed also that each 8-C.P. (33-watt) lamp uses 18 units = 6,123,546, with 20 per cent. spare, the load-factor comes out ≐ 13·8.

The design of 44 converting points in those districts required that, including spares, each transformer station should have, on an average, at least 275 kilowatts capacity.

The three first permanent sub-stations, the sites of which were secured by, and the structures designed by, myself, were—

1. Pancras Lane (Bennet shere-hog), with space for transformers having a capacity of 450 kilowatts.
2. Nicholas Lane (St. Thomas Acorn), with space for 480 kilowatts.
3. Queen Victoria Street (St. Nicholas Cole Abbey). This is a double station, and has space for 648 kilowatts.

Of these, I only show the design of the first, it being situated under exceptionally difficult conditions. (See Fig. 14, &c.)

TRANSFORMATION.

As has been said, little progress could be made with the selection of sites for permanent transformer stations before July,

* It is quite certain that this ideal condition of efficiency can only be achieved when a completed system is at full work; at lower loads it will often go down to 76 per cent.

1891, as the general scheme, upon which their relative positions much depended, was still under consideration. General Webber.

To distribute the current generated in the pioneer stations, three temporary transforming stations were improvised, viz.—

One in Queen Victoria Street, in the basement of No. 47.

One in the basement of the Mansion House.

One in St. Swithin's Lane, under a restaurant.

In no case were these suited to become afterwards permanent stations, both on account of size and circumstances of surroundings.

In the transformers first delivered the secondary windings gave a pressure of 1-20th that of the primary; and, as the current is delivered at an E.M.F. of about 2,050, and it had to be distributed in the three-wire mains with an initial pressure of about 205 volts, they had to be coupled two in series—an arrangement which would disappear with the delivery of the contract transformers.

It early became evident that the price, by way of rent, that would be demanded for adequate space in, and access to, existing buildings, was prohibitive in the more costly areas. For instance, in Lombard Street, where every square yard is said to be worth £1,000, it can readily be conceived that £500 a year was asked for a small room in the basement. With this in view it behoved us to look for what we required to the space under those portions accessible to the public, or not available for building purposes.

Careful searching showed that many engineering and financial difficulties existed.

For instance, at some points where there was evidently ample space below the surface, a prohibitive price was asked for the means of access to it through private property; and, again, at many such points, space for access within the area used by the public could not be obtained, for various reasons of public convenience and safety.

In time our attention was turned to the old City graveyards, and, after long negotiation with the parish authorities, and with the Consistory Court and the Commissioners, leave was obtained at a fair cost to use a small portion of two of these open spaces in Pancras and Nicholas Lanes, so as to provide shafts for descent

General Webber.

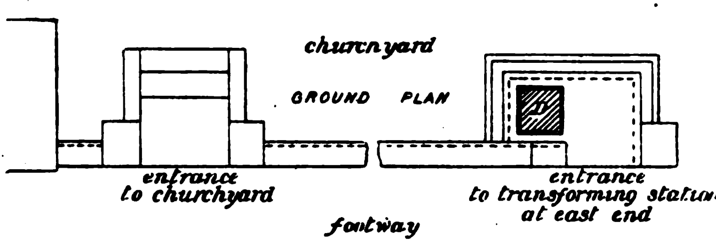


FIG. 14.

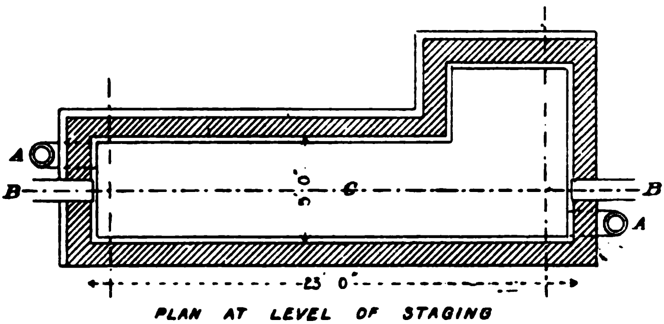


FIG. 15

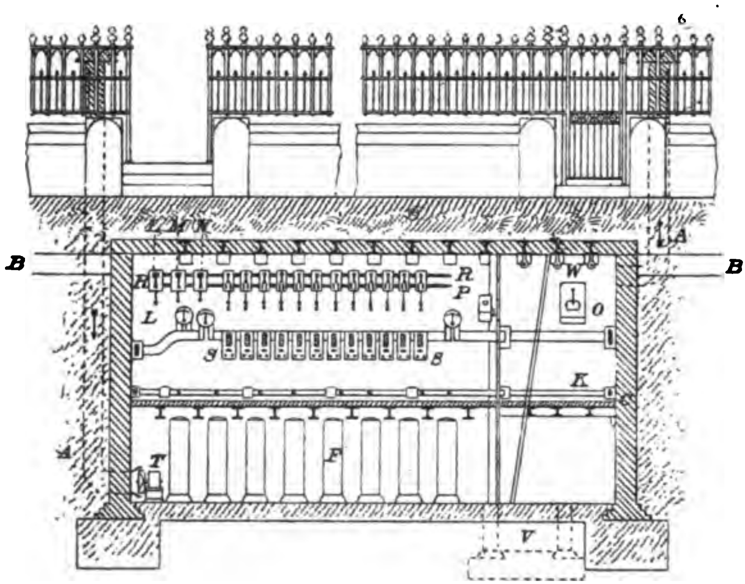
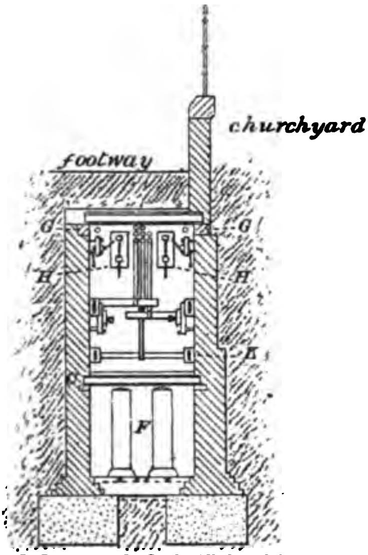


FIG. 16.

to the contiguous chambers to be constructed by leave of the Commissioners under the foot or roadways. General Webber



SECTION AND ELEVATION OF WEST END
FIG. 17.

But, even with this facility, the space below was in one case—namely, Pancras Lane—extremely limited, through the existence of large main sewers and water and gas pipes. In excavating, large quantities of human bones were met with, which had all to be transported carefully for extramural reburial.

The drawings show the structure and the conditions of housing the transformers and switch-boards and connections. Under such circumstances every inch was important, and it was to the suggestion of my chief assistant, Mr. Nisbett, that the plan of placing the transformers, F, below the floor was adopted in that station. Height was the most elastic dimension, and it will be seen that the attendant standing over the transformers on a stage, C, has sufficient headway to stand up and attend to the board, S, one on the north, another on the south side.

The floor of this stage is made of wooden squares, each of which can be taken off independently, and the top end of the transformer underneath exposed. When required to be removed, it is lifted by tackle suspended to a ring (as at W, Fig. 16) in the arched roof, and, being received on to a hand truck, it is moved along the floor to the bottom of the entrance shaft, and there, by other tackle, carried by a tripod standing above on the dwarf walls, lifted up to the surface, where it can be lowered on to a suitable trolley and taken away.

B (Fig. 16) shows where the conduits enter the station at the east and west ends.

General Webber.

D is the entrance for access to the descent by ladder into the staging.

F indicates the 18-kilowatt transformers.

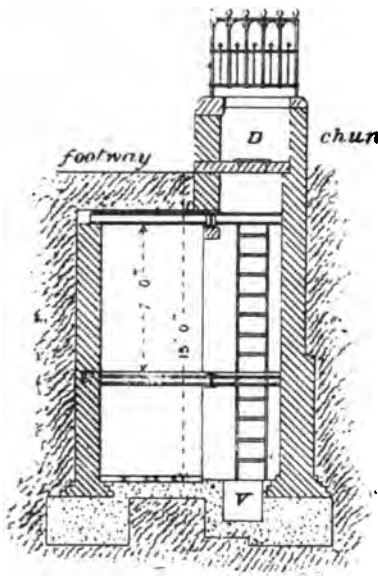


Fig. 18.

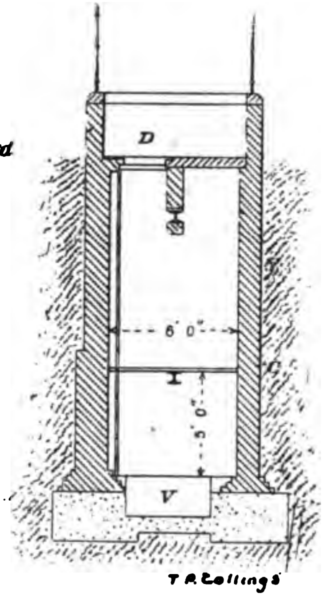


Fig. 19.

G (Fig. 17), the position of the primary 'bus bars on each side.

H (Fig. 17), the main primary switches.

K (Fig. 17), the low-tension middle bar which runs round the tension.

L and N (Fig. 16) are switches for connecting at high tension with other transforming stations.

M (Fig. 16), a switch to divide the station in two for repairs.

O (Fig. 16), a recording voltmeter.

P (Fig. 16), the telephone to the generating station.

R (Fig. 16), one pole of high-tension bar, with a switch to every two transformers, and Brush-Mordey fuses.

S (Fig. 16), low-tension switches on 'bus bar, with a switch to every two transformers, and separate fuses.

T (Fig. 16), motor and fan for ventilation.

Drainage by a sump, V, and ventilation by large upcast and downcast shafts, A, A (Fig. 16), are provided, as well as means of

telephonic communication, P. The cost of the builder's part of the structure, when completed, is about £430, with an annual charge for the way-leave of about £5. General Webber.

The honeycomb space under the staging floor should be able to receive 45 10-kilowatt transformers, but of which 40 may be assumed to be in use. The cost may be considered in the following way:—

	£
The present value of £5 a year for 21 years, at 5 per cent.	64
Cost of building construction	430
„ transformers and fittings, as per contract—400 kilowatts, at £7 ...	2,800
Add 5 per cent. for supervision and contingencies	182
Total cost of the transforming station ...	£3,476

To arrive at the capital cost of the plant between the generating stations and the low-pressure feeders, it is necessary to add the cost of two concentric mains; and this I have taken from a table that I prepared which enables me to appropriate with very fair accuracy between the conduits for various purposes the cost of the underground work.

In this case the distance is about 1,200 yards.

Carried down	£3,476
Two 2½-inch wrought-iron conduits, at 4s. 4d. per yard	520
Two 0·154-inch concentric high-insulation 1,200-yard cables drawn in and connected	1,150

These figures give a total capital outlay of £5,146, which will be repaid, interest and principal, at 4 per cent. in 21 years by, per annum, £161; to which should be added at least 2½ per cent. depreciation and repairs—say £136—and £70 for attendance and small stores: total, £367.

Again, assuming a total consumption of about 18 units per 33-watt lamp fixed, and 12s. the gross earnings per lamp per annum, and allowing 96 per cent. efficiency as before, and the

General Webber.

equivalent of 15,000 8-C.P. lamps connected with this one station, or say £9,000 per annum, the above annual charge will represent 4 per cent., being a standing charge on every unit sold.*

It being very desirable that the works of distribution in the City should receive efficient criticism, Professor S. P. Thompson was (at my suggestion) asked, in October, 1891, to advise and report, which he did; and I regret that circumstances permit me only to give the sense of his reports.

He dealt with the subject of any possible advantage from the use of low-tension dynamos and step-up transformers at the generating station, in comparison with the generation and transmission at 2,000 volts as specified, without recommending any change in the designs.

He recognised the extreme difficulty, in certain thoroughfares, of getting ways for the laying of conduits; in certain rich blocks, of getting a cellar for a distributing station; and the necessity for the principal routes to run north and south, not east and west, because the generating stations were on the south side.

As an example, he regarded Cheapside as practically an impassable street; as it runs east and west, "as almost useless for "the purpose of a route." That shops in it must be approached through side streets and from the rear he considered in reality as no disadvantage, "for lamps are wanted most, not in mere frontages, "but in back offices."

* A useful comparison may be drawn between the cost of these 2,000-volt mains and low-tension mains at 200 volts from the generating station to the same distributing centre. A loss of 2 per cent. in the high-pressure mains, and of 4 per cent. in transforming—total, 6 per cent.—in the former, may be fairly balanced by a loss of 15 per cent. in the latter. The additional size of the low-tension plant is counterbalanced by its lower price. The low-tension main, required to carry 400 kilowatts at 200 volts pressure through 1,200 yards of distance with a loss of 15 per cent., would be about 4 square inches of copper in each outer conductor, and 2 square inches in the middle wire. Such a line, using the largest insulated cables made, and drawing them into 10 3-inch "ways" of casing, would cost more than £15,660, representing an annual charge of £490, or 5·4 per cent. on each unit sold. Mr. Crompton will, I hope, give us the cost of the same sections of bare copper strip laid in culverts on his system, if he can keep his culvert, including thickness of walls and *flow*, within 160 inches sectional area, and at the same time carry it along where he has to make a change of direction every few yards.

He thought that there was the less need in the central areas to trouble about keeping them of equal size, since the distances from one sub-station to another were necessarily short. Having secured a sub-station in any one spot, it was easy to estimate, from the accommodation it affords, the extent of the district which it will subserve. General Webber.

He told me that the general plan I had prepared of distributing the alternating current at a pressure of 2,000 volts by mains to transformer sub-stations "could not be improved upon," and agreed entirely in principle with the general plan of distribution as provisionally set out in the maps shown this evening; and, further, approved generally the size of areas assumed in those maps to be suitable, and that the richest areas so mapped out are the eight areas surrounding the Mansion House (see Fig. 20) marked respectively C^1, C^2, C^3, C^4, and E^1, E^2, E^3, E^4.

The diagram map shows eight central districts in the City which were presumed to be those richest and having the largest immediate demand.

He agreed entirely with me in deprecating the provision of mains, through long streets, as was suggested by the design of the preliminary work in the pioneer contracts, and saw the need to break up long streets into sections, each such section to be supplied as part of a compact surrounding area.

The exact delimitation, even, of the individual areas he considered a less important matter than their compactness, solidity of work, and efficiency of supply.

At that time, and with the same gentleman, the question of automatic switching of a bank of transformers was discussed. It was a novel one as regards experience. We regarded it as essential, that, although at first manual regulation with daily shifts of attendants could not be avoided, eventually it would have, for economical reasons, to be done automatically. And in connection with this the inventions of Messrs. Gordon, Mordey, Tomlinson, Ferranti, and Kapp were considered. Of these well-known electrical engineers some are present, and will, I hope, give us the benefit of their remarks on this very interesting and important part of the subject.

General Webber.

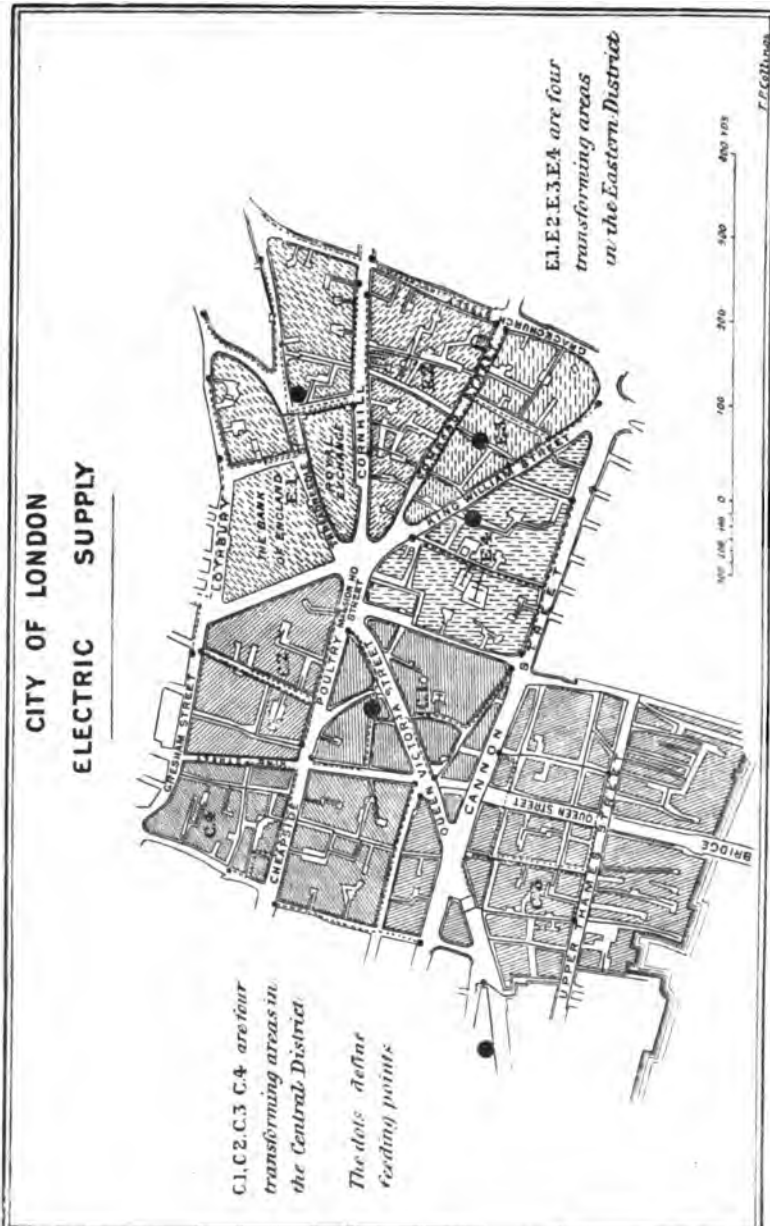


Fig. 20.—Centre of City.

EXECUTION OF THE CITY STREET WORK.

General Webber.

Although it may not fall to the lot of any present to have to carry out a similar work under the same conditions, it seems to me that a short account of a portion of what was done in the City streets may prove instructive to engineers.

Our papers are generally very full of technical interest, but few ever narrate the practical working engineer's experiences. This must be my apology for some diffuseness.

Enforced inaction for an engineer is always irksome, especially as he is well able to anticipate the loss and over-work that must follow through dilatoriness of those whose duty it is to make up their minds.

Such was my position between July and December, 1891, when valuable time was lost, and heavy and pressing work requiring to be completed by the end of February, 1892, had to be suddenly put in hand.

Fortunately, I had foreseen the rush that would come, and had engaged and organised my office and staff so as to be ready to go to work when required, and had also called for and received tenders for the various kinds of articles of plant and materials (several of which had to be specially designed) that the work would require.

The chief difficulties that had to be faced, besides those inseparable from street work in the City, were (1) the time of year (all the fine autumn had been lost), with its wet, mud, and fogs; (2) the difficulty of readily finding a sufficient number of *suitable* foremen to take charge of such work; (3) the inconvenience caused to the public by having 100 yards of footway "up" in nearly 30 different places at one time.

My estimates of the cost of the work had been based on the assumption that it would be carried out under our own staff, by hiring labour, and by purchasing tools and material, with a reasonable rate of progress. There was no doubt whatever that the intermediary of contractors would be wasteful, even although it was easy to find road and paving contractors in every city of the kingdom.

Time being precious, and the Commissioners threatening, my

General Webber. ideal could only be partially carried out. Tenders had therefore to be called for for separate sections of the obligatory streets; but here the obvious difficulty of price had to be faced. No contractor would quote to lay anything under a City footway without at least 100 per cent. margin, unless he could first take up the surface. But this first taking up was not permissible. Tenders under such conditions were obviously objectionable.

Then, considering that we wanted several contractors to go to work at once, besides our own gangs, it would have sent the price up a hundred-fold if their tenders were to include the supply of tubes, cases, and material, because they would have been competing for such unprecedented quantities in the same market.

There was only one course to follow, namely—

(1.) To purchase all the materials ourselves.

(2.) To prepare a specification and schedule of measured prices especially suitable and confined to the kind of work.

(3.) To pay for the work under measurement.

As regards the first, namely, the material:

Wrought-iron tubes, although a considerable stock is to be found amongst makers, are not held in quantities representing hundreds of miles, particularly of the quality of iron, and lap-welded, that we wanted. Our tests of samples were necessarily hasty, but the steam hammer, though rough, gave us a pretty fair indication of toughness. (Samples of tubes that had been subjected to tests are on the table.)

The very fact of so large a quantity being wanted, instead of enhancing the price, enabled us to do what is called "break the "ring," and I believe it is one of the very few cases in which tubes have been sold some 20 per cent. below "ring" prices. All the tubes were treated with Angus Smith compound.

As regards the Callender-Webber casing, there was only one maker; but here again foresight on behalf of the City lighting had a long time previously provided for special rates in favour of that particular work. At the same time, I cannot speak too highly of the great efforts of Mr. Tom Callender at that time to extend his company's means of output, and that at very short notice. I remember that at one time the bitumen we were

bound to lay underground in January, 1891, was still, in Christmas week 1890, on board ship in the chops of the Channel. General Webber.

As regards the second, namely, the specification and schedule (of which a copy may, if the Council permits, be attached), it is sufficient to state the former consisted of 44 clauses, and that the latter had 55 items, which the tendering contractors were asked to price.

But even with these precautions it was felt that, in the case of the most difficult streets, no contractors could be asked to tender at all except they were allowed to charge for whatever they paid out, and then with no obligation to meet all the liabilities for damage to person and property in the most crowded and intricate places in the whole world.

To our own engineers and men the work in such places as Cannon Street, Thames Street, Cheapside, Poultry, St. Paul's Churchyard, and around the Bank, &c., was allotted.

In the 22 streets in the Eastern and Central districts which remained to be dealt with at the end of December, the total length of trench to be excavated, and completed with conduits and boxes, was nearly 24,000 yards, of which 9,700 was allotted to the company's gangs.

There was only one month to do it in to carry out the conditions of the contracts with the Commissioners.

Three contractors at first—afterwards a fourth was added—competed successfully.* The abstracting of all the tenders showed a variation on the average work between £188, the highest, and £79, the lowest, per 100 yards of work. The highest tender accepted was at the rate of £128 per 100 yards. The same work in the more difficult ground done by the company's gangs cost only £60, including the cost of the plant used by them.

The average cost of the materials was about £118 per 100 yards.

The actual cost of the work essential to be completed in February was about £59,000. The maximum rate of progress

* Nine firms tendered.

General Webber.

was attained at the beginning of March, 1892, when 1·65 miles of trench was completed in six days' work.*

A glance at the map (see Fig. 20) will show that in the heart of the City there are eight transformer areas designed; and, naturally, as soon as the main thoroughfares were completed, to the completion of conduits in the lesser thoroughfares streets and courts of these areas was immediate attention turned.†

It will be readily understood, by a glance at the plan, that the

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* An analysis shows that the 4,260 yards by one of the contractors, at £128 + £118 = £246, cost £3,069 more than it would have cost if done by the company's gangs; that the 4,010 and 5,270 yards of the two others respectively cost £2,560 and £1,265, correspondingly, more; giving a total of £6,894.

But it may fairly be said that, if the contractors had tendered to do the work when the days were fine and long, their prices would have been 5 per cent. less—say £723.

It may be instructive to young engineers present to realise that, if the adverse conditions I describe could have been avoided, a saving of about £7,617 on what actually cost over £30,000 would have been effected; and that is exclusive of the advantages in the minor results in the form of better "finish" when the work is done under one's own foremen.

If the same work had been carried out at the rates of the highest tenders accepted, it would, including material, have cost £72,000, and if entirely in the way my estimates contemplated, the costs would have been, correspondingly, £40,000; but in neither event, having been begun in December, would it have been all done, as was essential, early in February.

† The amount that had to be paid for the work done in the streets by the pioneer contractors (already referred to) was £22,850, which, added to the previously stated amount, came to a total for the main thoroughfares of the Eastern and Central districts of £81,850. In the whole City there are 92½ miles of frontage, and in the eight special areas there are 22,000 yards. If the average demand for lamps is 2·1 per yard, we get 46,200, or about 6,000 per sub-station area; but, being the richest areas, three lamps per yard, or 8,500 per acre, was estimated. By March, 1892, the cost of the work (not done by contract) could be pretty closely detailed, and the cost of the conduits in portions came to a little over £17,000; giving a total for the completed street work in the main thoroughfares and eight sub-districts of the Eastern and Central districts, exclusive of conductors (except a small quantity of cable provided under the pioneer contracts, which is included), of £98,850. Of this, the length of trench completed by July, 1892, was 43,000 yards. I have little doubt we shall be told that most of the lighting in those areas is with 16-C.P. lamps. In this respect, I think it is evidently the wrong initiative policy to try to make up a big load before you are ready, in order to make a fair show, instead of keeping it down when first starting by encouraging in every possible way an economy of light by the use of 8-C.P. lamps. It is well known that I have been from the first an advocate of this policy, and I now attribute our measure of steady progress without a breakdown, and of permanent success at Chelsea as being largely due to it.

streets bounding the areas having been completed with all the "ways" actually necessary, and that could be put in, the internal cross streets could be provided with all that the future load could possibly demand for feeders of any size. General Webber.

A more precise idea of the cost of this kind of work laid in streets presenting exceptional difficulty is given below.

In an example of the streets in question only eight "ways" could be introduced under the footways on each side, viz.—

	Ways.
In Callender-Webber casing	3
In $1\frac{1}{4}$-inch tubes	4
In $2\frac{1}{2}$-inch „	1
Total	8

The length of the two sides, taken together, inclusive of the lengths occupied by boxes, is 1,328 yards.

The cost of taking up the surface and temporarily relaying it, at 3s. 9d. per yard lineal, was	£250
Laying conduits and pipes, at 1s. $3\frac{1}{2}$d. ...	85
Cost of „ „ at 8s. 6d. ...	718
Superintendence, storekeeping, cartage, sundries...	78
Small stores and blacksmith's work ...	27
Wear and tear of plant, and contingencies	116
Cost of draw-boxes and service-boxes where actually required	99
Approximate cost of restoring the surface, performed by the Commissioners' contractors, and on their schedule ..	554
Total	£1,927

Or £1 9s. per yard lineal of trench, exclusive of cables.

The equipment of this line with cables of the following sections, namely:

2 of 0·3 square inch section of copper ...	for low pressure,
1 of 0·15 „ „ „ ...	
4 of 7/16's	for high pressure,
1 of 0·158 square inch (concentric) ...	

General Webber

costs, in addition, £2,037; giving a total cost per yard lineal, inclusive of cables, of very nearly £3.

Including casing used for house services, the total length of ways in bitumen concrete casing laid in the streets and areas named up to July, 1892, was—

In casing unsheathed with iron ...	4,356	yards
„ sheathed in iron ...	148,068	„
Total	152,424	„

Or over 80 miles.

The internal diameter of these varied between 1 inch and 2⅜ inches.

The largest proportion of these were of the triangular form (exhibited this evening).

The total of 1¼-inch wrought-iron tubes laid was 173,000 yards, or 98 miles; of 2¼-inch wrought-iron tubes, 164,000 yards, or 93 miles. Total of ways of all sorts laid in the City between December, 1891, and July, 1892, 271 miles.

Of the Raworth-Callender-Webber conduit (Fig. 21), of which a sample is also exhibited, 212 yards, containing four ways, were laid in Queen Street. This was an experiment, and is an example of paper-lined ways bedded in bitumen and lying in cast-iron troughs, with separate cast-iron joint-pieces, and cast-iron covers bolted down.*

The durability of the paper has yet to be tested, but of this I have little doubt, if it is thoroughly impermeated; the only drawback is that they cannot be easily bent during laying, and that, as laid in the City, the cast-iron cover has to be cut through with a cold chisel to make a house service connection.

The sheathing of the Callender-Webber cases was mostly

* This latter system, called the "Callender-Raworth-Webber," in which I am joined with those gentlemen by an act of courtesy on their part, is chiefly attractive to me through the possibilities it offered for the use of bare stranded copper. Since then I have brought out, in conjunction with those gentlemen, a further development, being a combination of the two systems above mentioned, called the "Webber-"Callender-Raworth" conduit, which I hope may be a step in advance in that much-to-be-desired direction. Of all the systems I am able to show examples to-night, it is by the kindness of the Callender Company.

made of No. 22 gauge sheet mild steel, which covered the three sides of a triangular and the four sides of a rectangular case, then General Webber

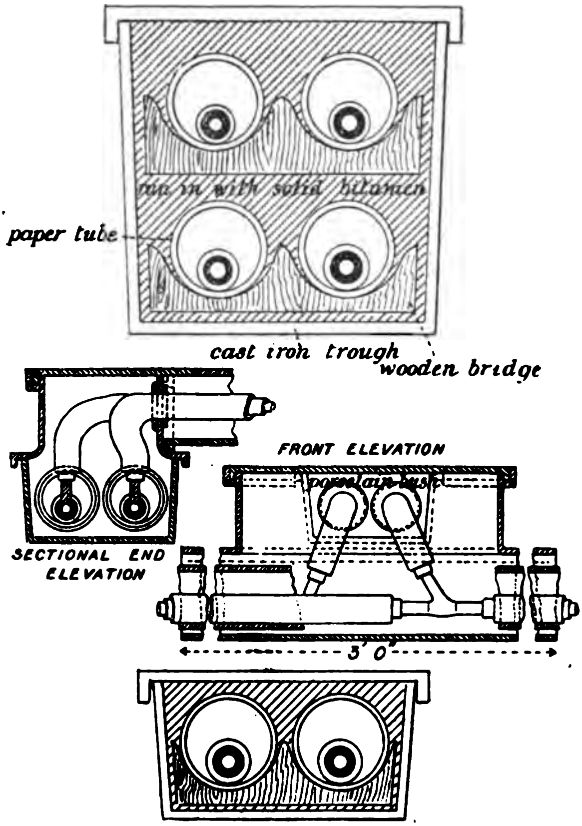


FIG. 21.—Callender-Raworth-Webber Conduit.

secured by studs or cut-in pieces, or 1½-inch hoop iron riveted, and the whole painted over with a bitumen solution. Sheathing for these cases was first used in the City work.

As is well known, the cost of the casing when it is triangular in section and has three ways of 1¼ inch diameter each is, without sheathing, 1s. 11d. a yard, which is 7⅔d. for each way; the same sheathed costs 2s. 10d., or 11⅓d. per yard

Nearly all the 1½-inch wrought-iron tubing laid (generally four tubes under each footway throughout)* cost 9½d. a yard,

* Two 1½-inch tubes are destined for the public, and two for private arc lighting series cables.

General Webber

which was an exceptionally low price for the reason I have already given; this is, against the first cost per yard of ways of the former material, less by 1⅝d. per yard. The advantages of the bitumen case, I think, more than counterbalance this: (1) durability; (2) there is less labour in making two bitumen joints than three screw joints (the former are 6 feet apart, the latter 12); (3) the bitumen is more easily cut to lengths and bent than the wrought iron; (4) there is no risk of rust sealing in the cables after they are in the bitumen ways, as often occurs with iron ways.

When you come to compare the 2½-inch ways in bitumen and wrought iron, the costs are as follows:—In the former each way in a *sheathed* case costs—

	Per Yard. s.	d.
With triangular section, three-way ...	1	9⅓
With rectangular section, „ ...	2	1

This at once compares favourably even with the exceptional low cost of our 2½-inch wrought-iron tubing used in the City, which was 2s. 6¼d. And when there are six 2½-inch ways in a case the cost per way comes out 1s. 5d. per yard, and a large economy is at once evidenced (increased if the cost of sheathing is avoided). But it must at the same time be noted that where we laid 18 (and more) 2½-inch tubes in the same trench with other conduits—for instance, throughout Thames Street—we might not have found room for three more six-way cases, which in cross section occupy more space than 18 2½-inch tubes.

I have not referred to the Western district, the contract for the public lighting of which did not require completion before the 5th November, 1892; but it may be stated that this work alone required 11,614 yards of trench, which, at an average cost of £1 12s. 1d. a yard, would cost £18,630, exclusive of spare tubes for other purposes.

CONDUCTORS.

As has been stated, the primary alternating-current conductors were concentric 0·154 inch, with high-class insulation; the high-tension continuous-current conductors were 7/16's concentric, except where the lamps are connected, also with high-class

General Webber

insulation; and the secondary conductors on the three-wire system of various sizes, has Callender extra standard type insulation.

The two first were drawn into 2½-inch and 1¼-inch wrought-iron tubes respectively.

The last was drawn into the three-way Callender-Webber casing, manufactured of three sizes—namely, with 1½-inch, 2-inch, and 2⅜-inch ways; in each of those the third way is smaller than the other two. (See the samples on the table.)

The largest were for feeders where necessary, and the two smaller for distributors.

In the eight sub-district areas shown on the map (Fig. 20) it is seen that no consumer's terminals would be more than 100 yards, measured along the main, from a transformer station; consequently, allowing the Board of Trade drop of 4 per cent. above and below the normal, the section of cables first drawn in, the maximum areas of the three conductors, taken together, was five-sixths of an inch; and very few feeders except quite short lengths were necessary.

It was considered that for a considerable time to come this would comply with a demand of at least three lamps per yard of frontage, the frequency of transforming stations being maintained. The impedance due to retardation was therefore negligible with those sizes.

The cable specifications giving the special conditions under which the manufacturers had to tender (of which a copy will be attached to this paper) had some special features, namely—

The same results of insulation as were prescribed for the tests at the maker's works were required after each length of cable had been drawn in, in the presence of the maker if he wished it, and before joints were made in it.

The maintenance of the insulation, except at joints, was guaranteed by the maker during three years from the date of it being drawn in, and if within that time the dielectric had deteriorated the maker was to replace the cable.

With a view to the company having the advantage of the market rate of the price of copper at the date of the quotation, the contractor was required to state the number of tons of copper,

General Webber.

made up in insulated cable, for which he would receive orders at that rate during one year.

As it became soon apparent that in each of the eight sub-districts above referred to separate transforming stations might not be obtainable, the question of a distance between them probably greater than had been calculated, required consideration, and the consequent enlargement of the sectional area of the copper in the conductors.

The first point that had to be considered was as to the saving that could be effected by the use of hollow-cored cable. With alternating currents having a frequency of 100 there is an inequality of distribution of the current over the cross section of the cable, and for practical purposes the penetration may be regarded as not exceeding ¼ inch from the outside of a cable of stranded copper, and therefore, if above ½ inch diameter, the copper in the centre of the strand is not useful.

These conditions led to the adoption of the Callender hollow cables for sizes varying between 0·4 and 0·7 of an inch sectional area as the simplest and cheapest form.

For instance, such a cable having half a square inch section of copper was made up of 38 No. 10's, or 30 No. 9's, in two layers round a hempen core, when the outer diameter of the copper is 1·05 inch.

For anything over ¾ square inch section of copper it was apparent that some form of multiple strand would have to be adopted; but for the supply then contemplated (even with only 600 amperes per square inch density) the maximum of 0·7 of a square inch was sufficient to provide.

As regards joints and jointing—that very important matter both in first cost and maintenance—I had examined every form that in 1891 had been before the electrical engineering world, and at that time had no reason to alter the opinion formed from long experience, that only when forced to adopt anything else by the construction or dielectric of the cable, could I recommend anything more simple practical or durable than the joint made of the same material and of the same form of covering as the cable itself; and this is applicable to both straight and T joints.

General Webber.

As regards the experience gained by the company in the matter of their mains since July, 1892, I shall hope the Institution may have very instructive information from the engineers who carried on the work after I retired from it. The best qualified is Mr. G. H. Nisbett, who since the autumn of 1890 had been my right hand in all matters connected with electrical distribution, and whose intimate knowledge of every part of the City work made it absolutely essential that he should pass from my service to that of the company when I left it.*

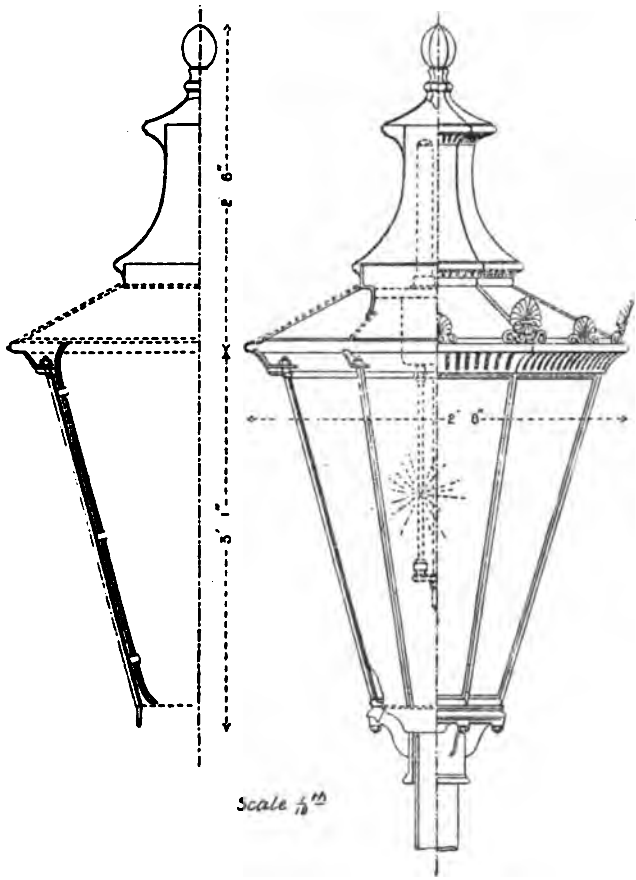


FIG. 22.—Street Lantern.

* I cannot refrain from also mentioning here two indefatigable assistant engineers on the same duty—namely, Mr. Buck (late R.E.) and Mr. Bates.

General Webber

Public Lighting—Lamps.

The lamp-posts and lanterns first erected in 1891 by the contractors, to the number of 72, in some of the main thoroughfares, under the pioneer contracts, did not meet with the approval of the Commissioners, and had all in time to be replaced.

The only portion which was allowed to remain was the lantern which had been designed by the Brush Company, and which I have illustrated, and called the "Raworth" lantern. My own views had advocated a different shape, having a wide pagoda roof, and sides at smaller angle to the horizontal.

In the case of the Raworth lantern, which is in use throughout the City, the dimensions were found to accommodate the Thomson-Houston arc lamp as well as that of the Brush; the interior is easily accessible; and the lamp, instead of being suspended, stands on a porcelain insulator. The other details are shown on the drawing, and a sample is exhibited.

As regards glass, Colonel Haywood was very particular in selecting one that was least absorbent of light, while being sufficiently diffusive of the arc.

The first sample, put in by the Brush Company, which gave the effect of there being four small blurs of light inside, was rejected as being too absorbing, and perhaps requiring too much labour in cleaning.

Three samples of glass were submitted to the engineer (see those in the lantern exhibited), and tested* by him in three street lanterns in use. They were respectively—

	Thickness. Inch.	Per Cent. Loss by Absorption.
Ground glass	0·058 ...	46·24
Opal	0·072 ...	25·18
Rippled	0·145 ...	21·73

The last was approved, and is now in use, and is the cheapest.

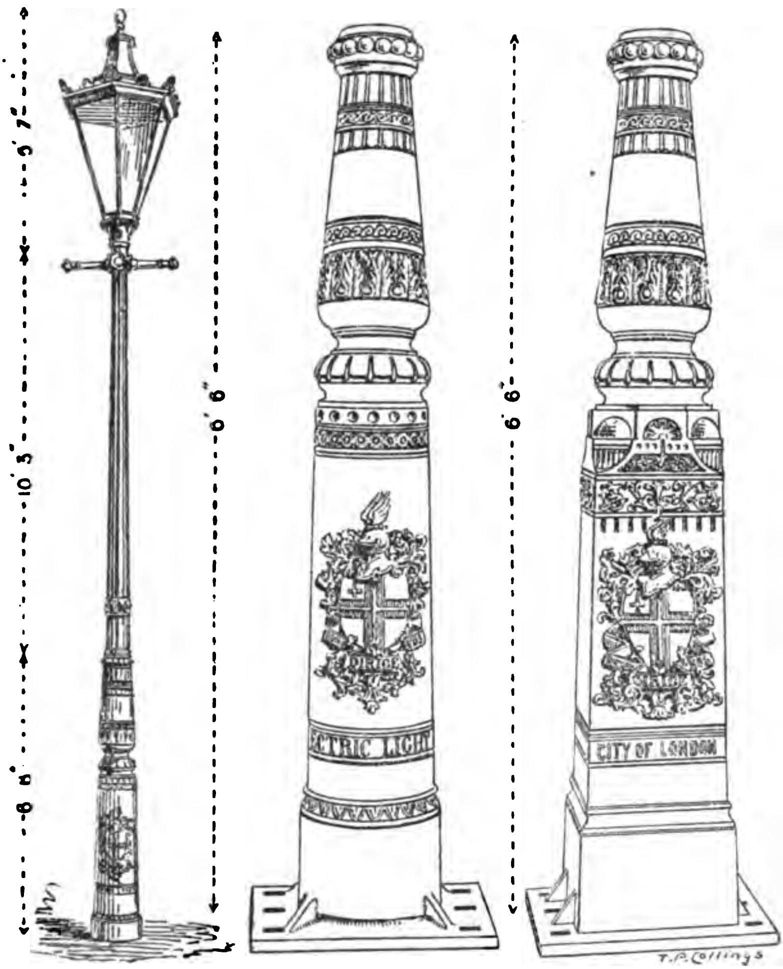
The lamp-posts, as finally designed and approved by Colonel Haywood, are in two pieces, the base having two forms; the smaller base, which is round, is fixed in the narrower footways.

As regards the shaft, one matter which required careful

* These tests were, I understand, made by Mr. Preece.

consideration was the means of assisting the lamp-trimmer to ascend and descend. General Webber

In any case, fixed projections below the lantern upon which



ELEVATION. SMALL BASE. LARGE BASE.

Fig. 23.—Lamp-Posts.

the man can stand at his work are necessary. These are the arms shown in the elevation. Fixed projections, or means of attaching them, were not admissible on the ornamental base; but something had to be done to assist the man to mount the shaft, so as

General Webber. to save the carrying and use of a long ladder in the streets. The permanent attachment of steps, for obvious reasons, the Commissioners would not allow.

Three methods were proposed, namely—

(1.) By the Brush Company, in which short pieces of rod iron, with a round head at each end, were passed into holes in the hollow shaft at intervals on alternate sides. These rods lay concealed all except the heads when not wanted; when in use, they were pulled out as far as the head on the rod within the shaft would allow.

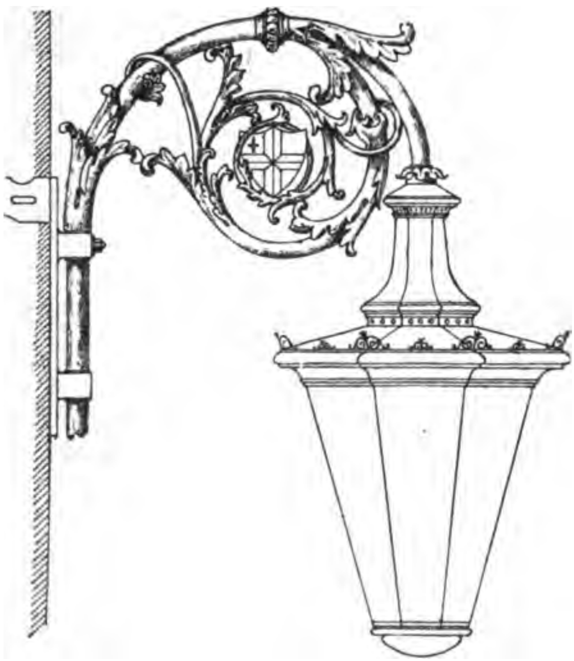


FIG. 24.—Side View, Lantern and Bracket.

(2.) By Colonel Haywood, which consisted in a structure like a parallel ruler, concealed in and bedded in each side of the shaft. When shut up, no evidence of its existence could be seen; when opened, the whole has the appearance of a ladder with a centre stave, and, but for complication and costliness, it might have been a very excellent design.

General Webber.

(3.) The plan which suggested itself to me was very simple, and has been adopted. It consists in using alternate side holes in the shaft, which are not conspicuous, and in having six or eight portable steps of light steel, which can be securely hooked into the holes as he ascends, and taken out by the trimmer as he comes down the post.

Where the footways are very narrow, and posts are inadmissible, it became necessary to use wall brackets; of one of these, illustrations (Figs. 24 and 25) in two aspects are given. The suspended lantern is the same in design as that on the posts, with some small differences in detail. It took a considerable time for the Commissioners to obtain the way-leaves for such heavy attachments to private buildings. The suspension gear was specially designed to allow the lamps to be independently and rigidly suspended inside the lantern, while the lantern itself is free to swing slightly and swivel round.

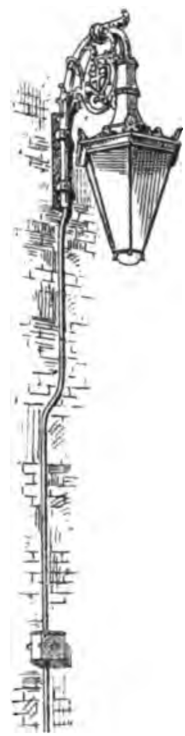


Fig. 25.—Lantern and Bracket, perspective, and Pipe under, &c.

In both cases—namely, in the base of the lamp-posts, and in a box fixed to the wall under the bracket—an absolute cut-out switch on an incombustible insulating base, approved by the Board of Trade, is provided. Each contractor has his own form.

In connection with fixing the posts more difficulty than might be expected was found. The base plates (Fig. 26) below the ground could not be by any means uniform in pattern. It was impossible to tell before the ground was opened whether the posts could be solidly supported by a deeply set base, or by one that spread out under the ground.* Several forms of modification of these conditions had to be provided

* In erecting the posts extra expense was incurred through having to open the ground a second time after the trench for the mains had been made. The Commissioners were responsible for this, owing to delays in approving of the patterns, and in finally deciding on the actual points to place each post.

General Webber.

for. In some cases heavy masonry and concrete had to be cut through and replaced.

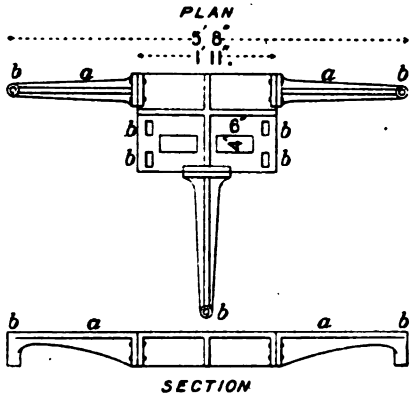


Fig. 26.—Underground Base of Lamp-Post.

Of the 371 arc lamps contracted for in the Eastern and Central districts, in March, 1892, the positions of 340 only had been decided on. Of the 340 points 37 were brackets.*

The contracts with the Commissioners provide for the substitution at 906 points of glow lamps of not less than 200 watts† for gas lights throughout the City where arc lights have not been put up.‡ The contracts with the two manufacturing companies specify that they are to supply and erect 100- and 200-watt series glow lamps; all arrangements in connection with the first installation to be experimental.

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* The weights and costs of these posts above the ground, and of the brackets and lanterns are as follows:—

	£	s.	d.
A large base weighs 9 cwts. 2 qrs., and costs ...	6	0	0
A small base weighs 6 cwts. 3 qrs., and costs ...	4	10	0
Each shaft and lantern gallery weighs 3 cwts. 1 qr., and costs	1	18	0
Each lantern weighs 3 qrs., and costs...	7	0	0
Each bracket weighs about 1 cwt., and costs... ...	2	2	0

† The prices to be paid by the City for glow lamp lighting is (sunset to sunrise)—

For a lamp of 200 watts	£10 per annum.
,, ,, 100 ,, ...	5 ,,

‡ It may here be stated that as early as 1888 every point in the City where arc or glow lamps would be likely to be required had been surveyed and plotted, under my superintendence. The deviation from that design has been very small.

General Webber.

The carrying out of these arrangements are still in the experimental stage. The Commissioners had the power to compel the company to complete them in the Eastern and Central districts by May last; but, in withholding their engineer's order to have this done, they have, I think, acted wisely in the interests of public lighting by glow lamps.

At the beginning of this paper I stated that the experiment on the Holborn Viaduct in 1882 had brought discredit on this means of public street lighting.

The experiment now going on by the City company in Basinghall Street is, I think, only calculated to produce the same result; but it is to be hoped the Commissioners will be as well advised in this matter as in the past.

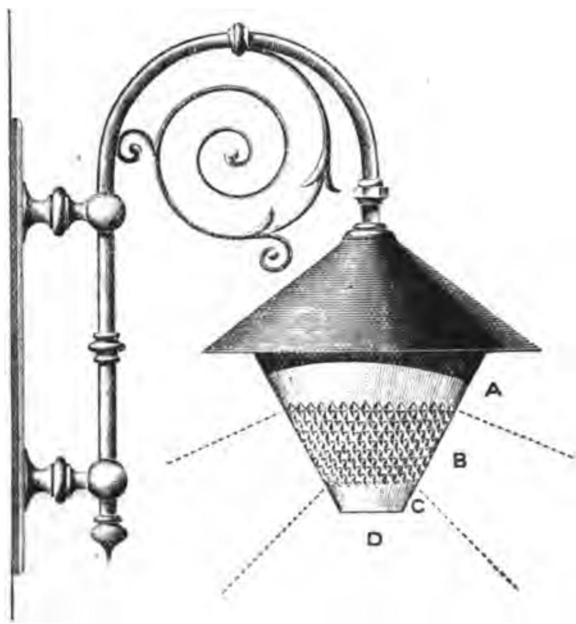

Fig. 27.—Wall Bracket, Glow Lamp Lantern.

The principles detailed by Mr. Trotter in his admirable paper before the Institute of Civil Engineers on public lighting by electricity are equally applicable in the case of glow lamps as in that of arcs. His dioptric lantern, which we have known ever

General Webber.

since the days of the Inventions Exhibition, is the mathematical example of that for which he contends.

It is many years since, at the Society of Arts, in a paper on glow lamps, I demonstrated that the exposure of the filament to the eye, or the eye to the filament, is an abomination.

I do not attempt to supplant Mr. Trotter's originality by showing a sketch (Fig. 27) of a street lantern with a hood, and inverted truncated glass cone underneath, the glass being cut up throughout a zone of its surface into diamond-pattern facets. There is nothing geometrical in their form (though there might be). They are only intended to intercept the direct view of the filament, within an area of space outside the lantern, and diffuse the rays of light from it. The simplicity of the design as regards convenience, &c., will, I hope, commend itself to the Commissioners; and I believe that, if posts in the small thoroughfares and courts were made entirely to disappear, and light ornamental brackets, with lanterns such as I have illustrated, were used, the City would in this respect have also taken the lead, and have set a good example to all other municipal bodies.

This paper, as its title shows, only deals with a portion of the great work of lighting the City of London. Necessarily, my duties as engineer up to July, 1892, required my superintendence of the starting of many works at present far from completion; and while in every case I have been careful to avoid enlarging on matters which could be better described by the engineers more directly responsible, obviously there are also several matters which might be regarded as more or less confidential. These I have avoided, and in selecting illustrations from figures have confined myself to those previously accessible to the profession.

In concluding, I hope I may be allowed to state that never was an engineer better served than I was by my staff, and that each and all fully justified their selection, equally those who were new to me and those who were old friends. It is no flattery to them to believe that my severance from the position of being their chief has in no way lessened the value of the services which they have since rendered to the shareholders of the City of London Electric Light Company.

The PRESIDENT: Your applause shows that you have very much appreciated the facts which General Webber has brought to our notice. I do not wish to detain you with long remarks, but I will at once call upon those of you who wish to discuss the paper.

Mr. D. R. DALE: I should like to ask a question. I do not profess to be an electrical engineer, but I should like to ask whether the electrical conduits ought to include telephoning. Mr. Dale.

The PRESIDENT: Which telephoning?

Mr. D. R. DALE: There are a certain number of conduits laid down through the streets of the City of London. I am led to believe that they are not entirely used for the purposes of electricity; some of those tubes are for telephonic purposes. Does the cost stated include those? Will General Webber kindly state the cost of the electrical conduits, and the cost of tubes for telephonic purposes?

Mr. HOWARD TASKER: I think we are all very much indebted to General Webber for bringing forward so many points of interest in this paper. I feel that he is capable of bringing those points together from a new point of view, owing to the fact that he has dealt with large undertakings of both alternating- and direct-current systems of supply, and can approach the matter on broader grounds than is usual from the advocates of either the one system or the other. General Webber has had the advantage of pioneering, and of being intimately associated with, a company which is in successful operation in Chelsea using direct currents, and on former occasions has given papers descriptive of the system employed by the Chelsea Electricity Supply Company, and, in consequence, is able to appreciate the merits of each system. I therefore think that the points that he brings to our notice are necessarily of much importance. I wish particularly to congratulate General Webber upon the marvellous rapidity with which he was enabled to carry out the work, and upon the immense quantity of work done in so short a time. He was, we all know, much delayed in getting to work at the outset, but when the "first sod was cut" he laid the mains at an enormous rate of progress. I think all who have had anything to do with Mr. Tasker.

Mr. Tasker. the laying of electric light mains appreciate the great difficulties which he encountered by the condition of things below the surface of the City streets. Probably many here to-night have seen the hopeless entanglement of pipes, &c., below the surface of the streets in the Strand; but, although the obstacles met with there were bad enough, it seems to me, from what one hears and from what one saw at the time, that the difficulties in the City were more than trebled.

Mr. Kapp. Mr. G. KAPP: I rise to ask a few questions. The author has given a large amount of information as to the way he has designed the distributing plant. This is interesting; but it would be of great practical importance to learn something about its working. For instance, one of the illustrations shows the transformers arranged in a sort of two-storied building sunk into the ground, and the transformers are at the lowest part. I should like to ask what will happen in case water gets in. I see the switch-boards are kept high up, which is the right thing to do; but the transformers are low down, and it is doubtful whether you can rely absolutely on the tightness of the casing. The most important section of the paper is perhaps that which deals with the mains. A great variety of systems were used, but I miss one, namely, that of iron-armoured cables, which seems the most practicable system in difficult ground. The sheathing effect of the thin steel plates seems to have been very slight, and that is what one would expect. It is extremely difficult to screen magnetic action by soft iron or mild steel, and especially if the steel is so thin as 22 gauge. The steel is likely to be soon eaten away, and then whatever small screening effect there was to begin with would be lost. The author's method of arranging the low-pressure network differs from that adopted elsewhere by the fact that each sub-station supplies a small network; but the extremities of that network are not connected with the extremities of the contiguous network. I should like to know what was the reason for avoiding an inter-connected network all over the City. The third point on which I should like to say a few words is the question of glow lighting in the streets. General Webber, towards the end of his paper, casts a doubt upon the practicability

of lighting a street by glow lamps; but it seems to me that glow lamps are the right kind of lamps for small streets. An arc lamp like the one exhibited costs at least £25 per annum to keep up; and to light a mile of streets with such lamps costs somewhere between £800 and £1,000 per year. Such an expense is only justified in lighting the most important streets of a town—that is, in parts of a town where the traffic is very heavy. In all other parts of a town the expense of arc lighting is out of all proportion to the actual requirements for light, and it would be sheer waste to give so much illumination. What we want is a moderate illumination. It need not be very strong, but it ought to be generally distributed in the streets, and for this purpose the glow lamp is, after all, the right lamp. It makes no dazzling show like the arc, but it is also vastly cheaper. Mr. Kapp

Mr. W. B. Esson: The paper before us is more statistical than technical; but I should like, with Mr. Kapp, to learn something about the endurance of the various makes of cable tried, and to hear more about the working of the system of distribution generally. Besides the Callender cable, other kinds have been used, and we want to hear something about them. As regards the working of the sub-stations, and the methods of regulation, we should also like to have some particulars on these points from the engineers who have been associated with the scheme. Although there are a large number of valuable statistics in the paper, there is not much information respecting the actual working of the system. Mr. Esson.

The President: Is not the paper a paper on the construction rather? I mean it is quite natural that he should not say anything about the working.

Mr. Esson: Perhaps so; but the working is what we want to know about chiefly.

The President: Gentlemen,—There are a good many points in this paper which should give rise to comments at your hands, and I will shortly call your attention to them. In the specification, to begin with, are some statements which appear to me to be entirely against the accepted facts of our profession. General Webber prescribed that the consumption of coal per kilowatt of The President.

The President. continuous current was not to exceed 7 lbs., and for alternating current it was not to exceed 5 lbs. This is directly contrary to the results which have generally obtained credit with us—viz., that the continuous current, kilowatt for kilowatt, can be produced at a cheaper rate than the alternating current; and it would be very interesting to hear some remarks on that subject, and to get at the facts of the case. Then another remark which General Webber made was about the twin telephone cables being protected against interference by this iron sheathing. To my mind, twin telephone cables—that means telephone cables with metallic circuits—surely do not want any protection at all; they protect themselves against any interference. It is almost invidious in me to say a word in favour of lead-cased cables, and I am only doing it because the other lead-cased cable makers seem to be absent to-night. You must, therefore, take my remarks in this respect as an *ex parte* statement entirely, and not as coming from one in my capacity as chairman of this meeting. These wonderful conduits which are shown here are said to have their various good qualities, in that you can easily heat them and bend them if you like. Now take one of those large lumps of bitumen, and imagine the case of a crowded street in the City, and that you have the task before you of bending the conduit so that the thing does not get out of shape in the curve. I would rather prefer laying the lead-covered cables, which can be threaded over and under gas pipes or water pipes, or any other obstruction, without any difficulty, and which can also be tapped for connection with customers in any place, just as gas pipes can be tapped. Will you also kindly recollect that I speak with experience of City work? because, as General Webber remarks in his paper, one of the three districts which were laid experimentally was given to our firm, and there we had the full complement of pipes and obstructions, including bones, to deal with. This arrangement with lead cables possesses the great advantage that you have not to take very extensive precautions against gas explosion, because naturally the gas cannot get into them. Then General Webber mentioned a matter which we consider a fallacy —viz., that hollow cables are of advantage if you deal with alter-

nating currents. Theoretically, the "skin effect," as I think it is called, exists with the alternating current, which, if it obeys all the laws that are made for it, ought only to travel on the outside of the cable. That effect is so very slight that you can make up for it by a very small increase in the section of the conductor; and if you come to compare the price—which, after all, is the thing a practical engineer has to deal with—of a hollow- or hempen-core cable, such as General Webber describes, with the price of a cable which has only a slightly larger copper section, you will find it much cheaper to make the section a little larger; because you must not forget that making a hollow-core cable implies that you have to put more insulator round it, and increase its dimensions generally, much more than you would increase the dimensions of the cable if you simply increase the copper by a small percentage. It cannot be too often repeated that, for practical engineering, money is the only thing which decides whether a plan should be adopted or not. The President

Mr. J. B. BRAITHWAITE: I rise to express my regret that in a body like ours, which ought to be above all things practical, General Webber has ventured to throw discredit, and to indulge in what appear to be unnecessary sneers against those who had the pluck to come forward to find the means for financing the City of London Electric Lighting Company. I noticed that he carefully omitted to read that portion of his paper, but, as I understand the whole of it is printed, I shall venture to call attention to one or two sentences. "As we all know," he says, "a very old way of "commencing to raise capital has been brought out under a new "name—namely, by the starting of a pioneer company, which is "one way of getting an instalment of capital together to make "a beginning. Of course there is no engineering justification for "it, but the financial physician has prescribed it, and hence this "first capital must be spent with a primary object of showing that "something can and will be done. The future of the under-"taking from the structural point of view may become quite a "secondary consideration, and, indeed, may be ignored if it "interferes with the parade with which it is intended to 'draw' the investing public." I venture to say General Webber could Mr. Braithwaite

Mr. Braithwaite. hardly do the Institution of Electrical Engineers a worse turn than by circulating an idea throughout the City that electrical engineers have no concern whatever with finance; and I should like to be allowed to recall to your minds the circumstances in which we were placed at the time General Webber alludes to, and which he carefully omits to mention in his paper. In November, 1890, when the house of Baring practically collapsed, the City experienced the greatest financial shock it had had since "Black "Friday," in 1866, and at that time it was the common saying in the City that you could not borrow 15s. on the security of a sovereign; whilst, at the same time, the Parliamentary powers for the two sections of the City, the Eastern and Central, would have lapsed and become absolutely null and void unless work had been commenced before the 28th of February, 1891, in one case, and the 29th in the other. Under those circumstances, it seems to me it was a matter of great interest to electrical engineers that there should be men found sufficiently plucky at that time to come forward and put down the hard cash to save those orders, to provide the fees for General Webber and other consulting engineers, and also to give the electrical industry probably the greatest opportunity it ever had of showing what can be done in the way of electric lighting on a large scale. Therefore I, for one, entirely take exception to the sneering character of his reference to the means adopted at a time of peculiar stress and strain in the City to save those orders from being forfeited, and to give this profession an opportunity of showing what it can do on a large scale in the greatest city of the world. It would occupy too much time to follow General Webber into the numerous statements made in his paper which many of us connected with the City of London Electric Lighting Company know to be inaccurate; but I ought to say that the suggestion he makes in the passage I have quoted—that the future of the undertaking has been ignored in order to make a show—is absolutely devoid of foundation so far as the City of London Electric Lighting Company is concerned.

Mr. Albright. Mr. J. F. ALBRIGHT: I should just like to say that I entirely endorse, broadly speaking, though perhaps not every word, what

my friend Mr. Braithwaite has said. I have had a certain amount of experience, although nothing like his, in trying to get schemes of this kind carried out, and I must say I find if you are to avoid any preliminary expenses, if you may call them so—in the paper they are called pioneer financing,—they can be called by any name you like,—but if you avoid all that, you cannot get these large schemes dealt with. So that I think—though there should be no question, probably, of sneers, or anything of that kind—a certain amount of this financing, which perhaps General Webber has not intended to be so severe upon as some paragraphs of his paper would lead us to suppose, is justified. I have not much to say with regard to the paper, because it seems to me it states a great number of facts, or at least they are said to be facts. I do not mean that they are not facts at all; I merely mean that they are statements, and I am not prepared to enter into a lot of argument to meet those statements. There are only one or two very small details upon which I should like to place my opinion before you. General Webber seems to me to be rather hard upon the glow lamp as a lamp for lighting public streets. I quite admit it wants to be properly put up and well used, but it should not go forth from this meeting that the glow lamp is inadequate to light public streets. My own experience is that the glow lamp—though, of course, not equal to the specimen of arc lighting we have before us to-night—is undoubtedly a useful lamp for lighting many portions of the public streets. I shall hope to hear a good deal of discussion with regard to the various questions General Webber has put before us about the cables. I cannot, of course, altogether agree with him with regard to the advisability of having adopted the Callender-Webber system to such a large extent. Some experience which I have had has not, at the end of a considerable number of years, shown me that you can rely on the Callender cable to be drawn in and out of the Callender-Webber casings. With regard to lead cables, I would join issue with our President, and say that they are not altogether to be relied upon, especially in cases like the City. I believe the best of those systems before you to-night is that of the wrought-iron tubes with a first-rate insulated cable drawn in. Mr. Albright.

Professor Thompson.

Professor S. P. THOMPSON: General Webber has done me the honour to refer to me in his paper because I have on various occasions advised the City Lighting Company upon matters on which they desired additional opinions. While General Webber has no doubt been very anxious to do me justice in quoting my opinions, I would beg to be allowed to remark that the abstract that he has made of certain of my views must not quite be taken as giving the whole. I particularly wish to say I do not impute any unfairness at all to General Webber in making these abstracts. As these reports I have made to the City Lighting Company are not my property, I am naturally debarred from referring to them in detail, that I might show what my real opinions are on certain points where only a portion of my opinions has been given. I would not, however, like it to go out that these matters, where I have been more or less fully quoted, are in any way my final judgment.

With regard to the use in series of incandescent lamps for street lighting, I should like to observe that it seems to me that success is very largely a question of the way in which the incandescent lamps are used. I would that we could point to more experience in the use of incandescent lamps in series methods of lighting, for I am quite sure that there are plenty of cases, both in large towns and in small—perhaps particularly in small—where arc lighting is not the right thing, where every arc gives far too much light—that is to say, far more than is wanted in the immediate neighbourhood of the lamp-post. Yet you cannot afford to put up posts frequently enough to illuminate the spaces between, and therefore a much larger number of much smaller lamps would be the obviously right thing. But the use of such lamps is restricted on account of the cost of a parallel distribution, while a series distribution would be much more *àpropos*. We have really very little experience in the use of series glow lamp lighting, and those who have such experience would confer a considerable benefit upon other electrical engineers if they would tell us what their experience has been, and how they have obviated the difficulties that arise in the use of incandescent lamps in series. With respect to the use of

dioptric shades for arc lamps, we all know how the City Company has carried out the attempt to distribute or diffuse the light of the arc by means of such shades. We all know Mr. Trotter's researches of 10 or 12 years back, and the very excellent principles from which he set out. This is a matter which would very well claim a discussion to itself, for there is much more to be said on the subject than perhaps many members are aware of. Quite recently in France an engineer, Mons. Frédureau, has been at work carrying out further into practical effect the ideas which were begun by Mr. Trotter in the production of dioptric shades, with forms of true geometrical significance impressed upon the glass. One thing certainly can be done in this way with the use of appropriately shaped glass shades—namely, to abolish for ever the dark shade which generally exists underneath an arc lamp. The very worst way to use an arc lamp, in my judgment, apart from the mere question of practical convenience, is to put it on the top of an opaque lamp-post. The best way is to suspend it in some manner, but, above all, to provide for a dioptric shade going underneath, which will diffuse the light straight down as well as sideways. The point immediately under the arc lamp, which is generally now the worst illuminated, ought, on the contrary, to be the best illuminated; and many of the objections that are so prevalent and so well founded against the use of arc lamps for interior lighting will be removed when once proper dioptric shades are to be had for the purpose of distributing and diffusing the light, which otherwise would be unbearable. I do not wish to add anything further, except that we are very much indebted to General Webber for this very complete history of the development of electric lighting in the City of London. Professor Thompson.

Mr. R. E. CROMPTON: General Webber has asked me in a footnote to his paper to give the cost of the same section of feeder in the form of bare copper conductors laid in our culvert system. I am very glad to give him this information, and I do it with greater willingness as it illustrates a point to which I have often tried to direct the attention of members of this Institution. I have always pointed out that up to a certain distance the real difference in the cost between Mr. Crompton.

Mr. Crompton. high- and low-pressure distribution lies in the cost of the feeders. In the high-pressure case we have a feeder consisting of a pair of high-pressure cables, and at the end of them one or more transformers in the transformer station; whereas the low-pressure feeder is a pair of conductors jointed to the network at the desired point by an ordinary junction box. I say advisedly "a pair of conductors," because I have never, in any of the three-wire systems of distribution laid out by me, used a feeder for the third wire, as I have found it unnecessary.

However, General Webber states that the cost of a low-pressure feeder 1,200 yards long, consisting of cables drawn into pipes, and having a total cross-section of 10 square inches (that is, 4 square inches for each outer conductor, and 2 square inches for the middle wire), will be £15,660, and asks me to say what would be the cost of a similar feeder on the culvert system. I believe that there would be no difficulty in constructing such a feeder, containing 62 tons of copper, for about £5,500; but if I were going to use such a feeder, I should not use it as General Webber proposes: I should use at least 220 volts instead of 200, and I should omit the third wire. If I work with the same percentage loss as proposed by General Webber, these two modifications would reduce my total section from 10 square inches to 6 square inches, and hence the total weight from 62 to 37 tons. Under these circumstances the cost of this feeder could be brought down to something between £4,000 and £4,500.

Of course this is on the supposition that we should find space throughout the entire length of the feeder for the culvert system; but it is fair to say that we rarely do find such space continuously. We find that at crossings, and at places where exceptional difficulties arise, we have to change the system from the culvert system to that of short lengths of cable drawn into cast-iron casing; and with conductors of such heavy section as this, this will materially increase the cost; so that, if we allow an average percentage of the total length of the feeder to be in the form of casing and cables, we shall have to increase the total cost from this cause up to about £5,500. These figures compare very

favourably with the large figure quoted by General Webber, and with the cost of the high-pressure feeder. Mr. Crompton.

If we go further, and compare the maintenance cost of the two systems, there is no difficulty in showing that the low-pressure feeder will be the least costly, as General Webber has given in detail the cost of upkeep of the high-pressure feeder, and he brings this out at £367 per annum. If I adopt the same figure for interest and sinking fund at 4 per cent., my low-tension feeder will cost £172 per annum under this head; but as many years of experience has shown us the maintenance of the culvert system is under half a per cent. per annum on its first cost, the maintenance charge on such a feeder should not exceed £20 per annum; therefore the total cost of this feeder would be £182 per annum, or just about half that of the high-pressure one.

In laying these figures before the meeting, I must again point out that in them lies the whole pith of the great controversy between high and low pressure. Nothing but lengthened experience (much longer than we have had at present) in the use of continuously insulated cables will tell us what the real life of these cables will be under working conditions. In most cases it would be a costly matter to open these cables up to examine them. Where cable systems have been replaced or withdrawn, the state of the cables has very frequently not been satisfactory. On the other hand, the culvert system has now been in use seven years, and it is so accessible for examination that every portion of the conductors can be seen and inspected almost as well as if the conductors were laid out on the pavement. Engineers now in charge of culvert systems are able to sign certificates that the copper conductors, insulators, and culverts are practically in the same condition as when first laid down seven years ago; so that, although we have not yet arrived at any finality in calculating the life of cables, we have arrived at a very definite idea of what the life of a culvert system will be, and are justified in forming the opinion that the upkeep will be excessively small for all time.

I think we must all thank General Webber for his paper, which must have taken a great amount of labour to compile, condensing

Mr. Crompton

as it does a vast amount of very useful information into a small space. It is quite impossible for anyone to discuss it in a satisfactory manner at the short notice that we have had, but I must say I have a strong sympathy with the gentlemen who have so successfully carried through the financial arrangements of this company at a time of unexampled difficulties.

General Webber.

General C. E. Webber: I can only reply to a few points mentioned by the speakers. As regards the question of telephone tubes, I can at once answer that my paper has not been a financial statement of capital outlay in any way in a complete form. The figure that was given, from which I deduced £75 per kilowatt, was one chiefly founded on the published prospectus and reports of the company. The financial statement of the capital expenditure on spare tubes, which Mr. Dale calls telephone tubes, is a matter on which I have not the power to inform him accurately. A remark that Mr. Kapp made is one which I very much regret is too true. It is that the discussion has been precipitated by my having curtailed my paper in the reading; but, like all these things, when you have put down what you have to say to make a complete account, you very often find there is a great deal more than there is time to read; and, as I had promised our President to keep within the hour, I found it necessary to do so by reading extracts, as Mr. Preece did the last evening we met. The question of the screening effects which Mr. Kapp referred to as being in a very small way due to the sheathing, is one which in the experiments I referred to, occupied my attention, because the sheathing followed on that experiment. The screening that we obtained in the case of the experiment was with wrought-iron tubes, which were placed upon the trestles, sometimes on one side, and at other times under and around the casing. There were no means of proving what the value of sheathing was, but it was thought essential that every precaution that could possibly be adopted should be resorted to. From my own observation at the time, I believe the only reason why I heard sounds in the twin wires was that, instead of being spirally twisted, they were parallel to one another; and, whatever that represented, still it was necessary, if possible, to

prevent all possibility of disturbing the telephone conductors in the event of their being laid not spirally twisted and parallel in the same trench. What the sheathing has done I have no means of telling, and I do not think without a very exhaustive experiment we can be sure that the money laid out on sheathing was not thrown away. Mr. Esson mentioned questions upon which in my paper I have carefully guarded myself from making any reference to—that is, the experience of working. That, I think, will best come from those who have had that experience, and it would be presumptuous in me to refer to it in any way at second hand. I have perhaps followed—I do not say exactly—in the steps of Professor Forbes in his Niagara paper. I have given you a paper which chiefly describes work of which the working result has still to be obtained, at the same time confining myself entirely and absolutely to work of which I had the designing, or superintendence of the designing, and mostly of the execution. The remark of Mr. Siemens on the 7 lbs. and 5 lbs. of coal is due probably to his not having had time to read the paper with sufficient care. The 7 lbs. was allowed as a well-known figure—namely, that the arc lamps are to be run by Brush and Thomson-Houston dynamos, from which greater efficiency of coal consumption cannot be obtained. A high-pressure continuous current is used, and if any other figure had been put than 7 lbs., the contractors would not have been prepared to accept it. The 5 lbs. as the expenditure of coal for the alternating plant, I think is a very good one, and one which there is every prospect of their being able to keep within. The other remark of our President opens up a very big subject, because it is one which you may say has produced as much discussion as the broad gauge and narrow gauge, or the breech-loader and the muzzle-loader. It is, whether you are to lay down underground in the first instance, lead-covered cables of sufficient number and size to meet all your possible future demands for low-tension distribution. If that is right, then there is no use putting in empty conduits for cables to be drawn in afterwards. The essential object of getting your conduits in is that you provide your ways in advance, and in excess

General Webber.

General Webber.

if possible, so that you may have ample room for your cables. Until we have figures which are at the present moment far beyond our reach—that is to say, the figures of the actual first cost and progressive cost of underground work in various great undertakings in great cities throughout the world—we cannot arrive at a conclusion. At present many undertakings are much in the position of the gas companies who began by laying down small pipes, then larger ones, and then larger still; whereas it is perfectly certain that if they had put in large ones in the first instance, they would have saved themselves an enormous outlay on extensions. As the President says, money decides the issue. I have stated a great deal in connection with the cost of work in this paper, and have done it with the view of leading your minds up to what engineering works of this kind will cost when carried out under various conditions of possible or imperfect economy.

Professor Thompson's statement as regards my quotation from what he told me, is entirely in accordance with what was my intention and spirit. I did not wish to quote him literally, but I wished perhaps to draw attention to statements of his which my paper fully supports. At the same time, it is natural that his views, as coincident with mine in 1891, should be pointed to in justification of steps which were taken in commencing and proceeding with such a great work. I think he has put it exactly in the way I should have put it if I had been in his place.

I am very happy to find that my figures in the footnote to which Mr. Crompton refers, have drawn out from him a statement which is of great value. But there is one point on which he does not answer me, and that is whether the £4,400 will construct a conduit which will be confined within the sectional area I have given.

Mr. Crompton: Yes.

General Webber: Of course, if he adds that it can be confined within that sectional area, then his figure is complete; but I doubt much if he can. My calculation of £15,000 was also a figure calculated from the cost of 3-inch ways being laid in the

General Webber.

ground, and very large cables subsequently drawn in; but whatever result there may be, or conclusion in your minds, from both these estimates and statements, I am only too glad that my paper has been the means of calling forth a comparison of figures of such very widely different import. Whether it leads you to give Mr. Crompton or me an order, I do not know, but I suppose I should be at the bottom of the list. The only matter of discord that has been imported into the discussion has been that the expression of "sneering" allusions to the procedure of financiers is laid to my charge. It was not my intention to do anything more than to describe the process by which capital is sometimes raised, and its effects on engineering. Unfortunately, it may be unavoidable; I am not prepared to say if it is avoidable. In spite of Mr. Braithwaite, I still regard it as regrettable that it should be associated with great engineering undertakings. I think that charge comes, perhaps, more ungraciously from the lips from which it emanated, because in the whole of my paper there is one story that runs through it, and that is, applause accompanying the record—and I think a very handsome record, and well-deserved—of the work of the company of which the speaker has lately become the chairman.

The President.

The PRESIDENT: Gentlemen,—I have now to call upon you to give a vote of thanks to General Webber for the very interesting paper he has brought before us. I will not enter into the points again, but I can tell you that we have the prospect of hearing a statement from Mr. Crompton on the actual works of low-pressure stations; and also a statement from other sources as to how these works, the origin of which General Webber has described, have been actually working in practice. I beg to move that the thanks of the meeting be given to General Webber for his paper.

The motion was carried by acclamation.

The PRESIDENT: I have to report that the scrutineers declare the following candidates to have been duly elected:—

Foreign Member:

Ernst Danielson.

Members:

The Marquis of Salisbury, K.G., F.R.S., &c.
Benjamin Hillier Antill.

Associates:

Walter McLellan Arnot.
Sidney Crouch.
John R. Dobson.
Augustus Treyer Evans.
Oswin G. E. Hansom.
Lucien Alphonse Legros.
J. Joseph Arthur Montealegre.
Percy W. Northey.
Henry Herbert Reynolds.
William Gould Rhodes.
Charles Turner.
Miles Walker.
James Whitcher.

Students:

Frederic John Bakewell.
Robert Birkett.
Alfred Brown Blakey.
Frank William Bowden.
Alfred C. Eborall.
Edward Ernest Hoadley.
George Reginald James Parkinson.
John J. Pease.
George H. Starr.
Cecil L. Sumpter.
Adolf Schoder.
Arthur Percy Strohmenger.
Frank Twyman.
Charles Yatman.

The meeting then adjourned.

The Two Hundred and Sixtieth Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, February 22nd, 1894—Mr. ALEXANDER SIEMENS, President, in the Chair.

The minutes of the Ordinary General Meeting of February 8th were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Students to that of Associates—

John R. Dick.	Albert Edward Frimstone.
Wilfred H. Everett.	Henry Home.
James Hermann Field.	Arthur T. Smith.

Percy M. Williamson.

Mr. H. C. Haycraft and Mr. H. E. Mitchell were appointed scrutineers of the ballot.

The PRESIDENT: I will now call upon Mr. Kapp to read his paper.

ON METHODS OF TESTING THE MAGNETIC QUALITIES OF IRON.

By GISBERT KAPP, M. Inst. C.E., Member.

The industry generally comprised under the term "heavy "electrical engineering" has of late years made such rapid progress that the question as to the kind of materials to be used has become of great importance. As regards the copper wire required in the construction of electrical machinery, certain standards regarding the size and conductivity have from the very first been Mr. Kapp.

Mr Kapp. adopted. The metal of commutator plates, size of wearing surface, type and number of brushes, dimensions of resistance coils, and other purely electrical parts of the machinery, have also, as a rule, been specified; but as regards the iron used no attempt was at first made to define it by specification. Makers of dynamos, for instance, broadly distinguished between cast-iron and wrought-iron field magnets, and got out their designs with reference to the magnetic properties each of these two kinds of iron was assumed to possess; but there was no certainty that the iron obtained did actually possess these properties. If the machines turned out according to design, well and good; if not, then the speed or excitation had to be altered so as to get the output right. This was the old and unscientific method of building electrical machinery. The modern method is very different, and far more certain. The manufacturer of a dynamo knows exactly what kind of iron he is using, and he is thus able to predetermine the performance of the machine with a degree of accuracy which formerly was impossible. This is especially of importance in large machines, as experimental runs to determine the characteristic at full load are not easily made, and are always expensive. In such cases it is preferable to cut a sample from the magnets, test it magnetically, and use the results of this test in designing the winding.

In some cases it is not even necessary to cut off samples and test them, as the manufacturers of forgings and castings for magnets offer now to supply these so as to conform to a certain magnetic standard, commonly defined by means of a curve in which the abscissæ represent magnetising force and the ordinates induction. Provided, then, the iron maker supplies exactly the material which he has promised, the winding of the machine can be designed without any preliminary experimenting. Iron makers are now keenly alive to the importance of this subject, and produce most excellent material. The testing of iron plates intended for use in alternators and transformers is another of those questions which had to be faced by manufacturers who wished to attain perfection in their work. As regards transformers, it will probably be admitted by all that the quality

of the iron is the most important factor in the whole design. To make a good dynamo with inferior iron is still possible; we need only use enough of it, and spend enough money on the copper to make up for the deficiency in the iron. With transformers this cannot be done. If the iron is bad, no increase in its bulk, and no amount of money we may spend on copper, will enable us to turn out a good transformer. The important point with transformer plates is not the higher or lower permeability, but the waste of power by hysteresis and eddy-currents; although to a certain extent the two go together, in the sense that a very soft iron having high permeability also has, as a rule, a small hysteresis loss. Plate makers, recognising the importance of small hysteresis, now offer their material with a guarantee that the loss with a given induction and frequency shall not exceed a certain amount per pound. Mr. Kapp.

Admitting, then, the necessity for magnetic tests of iron, the question as to method arises. There can be no doubt that the methods adopted by Dr. Hopkinson and Professor Ewing in their classical researches give the most accurate results; but the very perfection of these methods forms a drawback to their adoption in engineering works where highly trained experimenters cannot be found. I have therefore adopted other methods, which do not aim at absolute accuracy, but which can be used by any one of the staff generally found in the test room of electrical engineering works. The apparatus required is on the table, and I venture to bring it before you because it has been in use for some years, and has given results which were always found sufficiently accurate for all practical purposes.

It will be convenient to divide the subject into two parts—one dealing with the testing of magnet iron, and the other with the testing of transformer plates.

Testing Machine for Iron Bars.

This is shown in Fig. 1 to a scale of 4 inches to the foot. For the principle on which it is based I am indebted to a little instrument devised some four years ago by Professor Silvanus Thompson, and called by him a "permeameter." In it the induction through

Mr. Kapp.

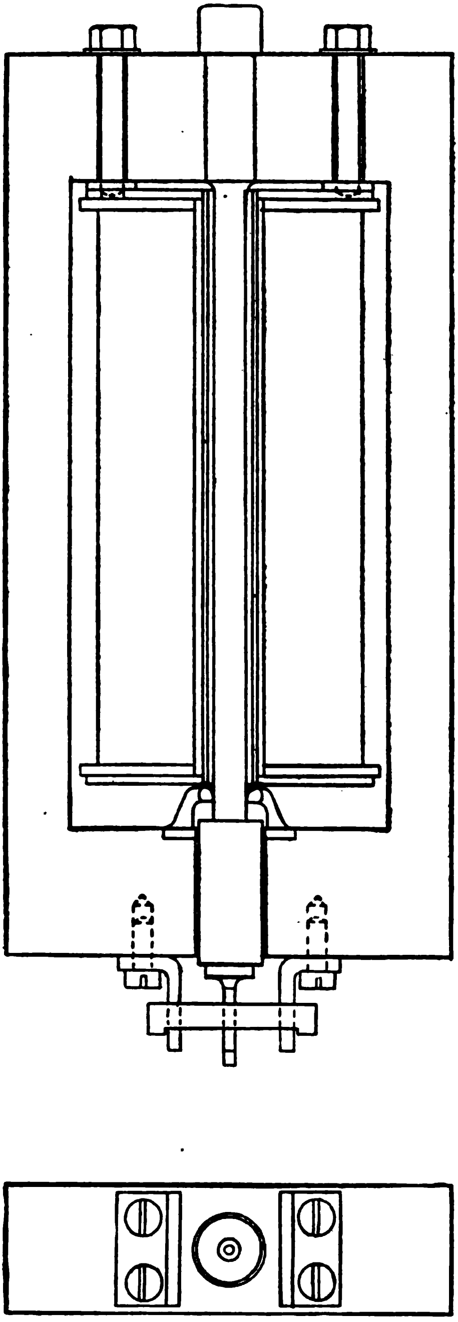

Fig. 1.
Scale—4 in. to the foot.

the sample bar is measured by the force required to pull the bar away from another piece of iron; and, as the induction is proportional to the square root of this force, it is clear that any small error in the measurement of this force results in a still smaller error in the determination of the induction. Thus, if his spring balance were wrong by 2 per cent., the error in estimating the induction would only be 1 per cent. So far, then, as the determination of B was concerned, the permeameter appeared to be an exceedingly accurate instrument; but this alone is not sufficient. We must have the relation of B and H, and, as part of the total ampere-turns applied is required for the magnetic circuit outside of the sample, certain corrections must be applied in the determination of H. It was mainly with the object of making these corrections both small and defi-

nite that I altered the design of the Thompson permeameter and made it in the form shown on the diagram. The instrument consists of a heavy rectangular frame, made of the best Lowmoor iron, well annealed. Within the frame is fixed a solenoid with subdivided winding, so that a variable, but known, number of turns can be placed in circuit by using the various terminals provided on the instrument. The object of this arrangement is to keep the current within such limits as will ensure the greatest accuracy in its measurement, whilst the magnetising force is varied between very wide limits. A reversing switch is inserted to facilitate the investigation of the complete cycle. Mr. Kapp.

The sample consists of a bar accurately turned, and faced at the lower end. The bar is kept larger at the upper end, where it passes through a hole in the frame—a fairly tight fit—and it is centred near the lower end by a little gun-metal ferrule. Below the bar is a soft iron plunger, guided in a hole in the frame, and provided with an attachment for holding a scale-pan and weights. The plunger is made larger than the bar, and has a fine hole drilled through it to ensure good contact over the rest of the surface. The dimensions of the plunger and the hole in the frame being accurately measured, it is of course quite easy to determine by calculation how much of the ampere-turns provided is required to overcome the resistance of the annular air space; and this is the only important correction required. The other corrections, such as the magnetic resistance of the frame, or that of the joint between the sample and the frame at the top, are quite trifling. Even the correction for the resistance of the air space is only important for low inductions. For inductions above 10,000 it becomes relatively small, and above 15,000 quite negligible. The method of using the instrument is as follows:—The sample, with its end carefully faced, is inserted from the top, and a small current sent through the solenoid, using the smallest number of turns. The plunger flies up against the sample and sticks there. The scale-pan is attached, and weighted until the plunger comes off. The exact point at which the weight overcomes the magnetic attraction is best determined by slightly varying the current by

Mr. Kapp. means of a rheostat; and I may mention that it is necessary to use a storage battery to provide the current. To work directly from a dynamo is impossible, as the slight variation in current produced by the irregularity in speed of the engine, or the flicking of a belt, is quite sufficient to make the tearing-off point uncertain. The current, number of turns in the solenoid, and the weight are now increased step by step, then decreased again to zero. The current is then reversed, and the operation repeated, so as to obtain the complete cycle. The values recorded are ampere-turns and tearing-off weight, in which is, of course, included the weight of the plunger and scale-pan. The greatest weight supported by a half-inch sample bar of good iron is about 45 lbs. I need not detain you by giving in detail the calculations for finding the relations between ampere-turns and H, or weight and B, nor the values of the corrections,* since these are purely elementary matters, and can be worked out for any testing machine of this type if its dimensions are known. The time occupied in testing a sample through a complete cycle is about an hour; one man manipulating the weights, and the other the current. The latter also books the readings.

I have used the apparatus before you in testing large numbers of samples of cast iron, wrought iron, and mild steel submitted to me for investigation by different iron makers, and some of the curves obtained are on the table. For obvious reasons, I do not mention any particular maker of magnet steel; but I may say generally that the samples of steel submitted to me were very good, and in some cases better than wrought iron. The good qualities of mild steel as revealed by the testing machine were

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* In the instruments exhibited, the corrections for top of sample, frame, piston, and air resistance collectively amount to $\frac{2 \cdot 37}{1,000}$ B ampere-turns, to be deducted from the total ampere-turns. Thus, for B = 12,000, which would be the lowest induction of practical importance, 28·5 ampere-turns would have to be deducted from a total of about 300; whilst for B = 15,000 the corrections would be 35·5 to be deducted from a total of about 1,500, and for higher inductions the correction becomes quite negligible. If P is the tearing-off weight in pounds, $B = 2{,}973 \sqrt{P}$; and if X represents the corrected ampere-turns, $H = \frac{X}{20 \cdot 2}$.

fully confirmed when the same material was used in dynamos and thus tested on a large scale. Mr Kapp.

Testing Machine for Transformer Plates.

My first attempt to make such a machine was a failure, but, as failures are sometimes as instructive as successes, I have placed the machine on the table for your inspection. In this machine I did not measure the power lost in the sample, but endeavoured to get an approximate means for comparing the permeability of different samples. An iron ribbon is coiled up to form a closed ring, and this is wound on opposite sides with coils so connected as to produce consequent poles over the two sides kept free from winding. The sample is made up of narrow strips into a flat bar, which is laid across the poles to form a magnetic bridge. The sample is surrounded by a pilot coil, and this is connected with an electrostatic voltmeter. If the same current is always sent through the main coils, and at the same frequency, then the volts produced by the pilot coil are supposed to give, roughly, an indication of the comparative value of the samples. The method was a failure, partly because permeability is not an absolutely reliable guide in estimating hysteresis loss, but chiefly because the uncertainty in estimating the magnetic resistance of the joints completely swamped any small differences that might have existed in the permeabilities of the samples. I therefore promptly abandoned this instrument, and set to work on another which would give directly that what we want to measure—namely, the losses at given inductions.

This instrument is shown in Fig. 2, drawn a third of full size. It consists essentially of a closed magnetic circuit of rectangular shape, the two longer limbs being enclosed in exciting coils. One long limb and the two uprights are composed of plates in one piece; the other long limb is formed by the sample plates, which are laid together so as to make up a certain weight, and are then bound together with tape and inserted through the top coil. The sample is fixed by wooden wedges. The coils are connected with a source of alternating E.M.F. sine function through a wattmeter, and the instrument is thus ready

Mr. Kapp. for use without further preparation beyond making up a bundle of plates into a sample bar and inserting the latter. The

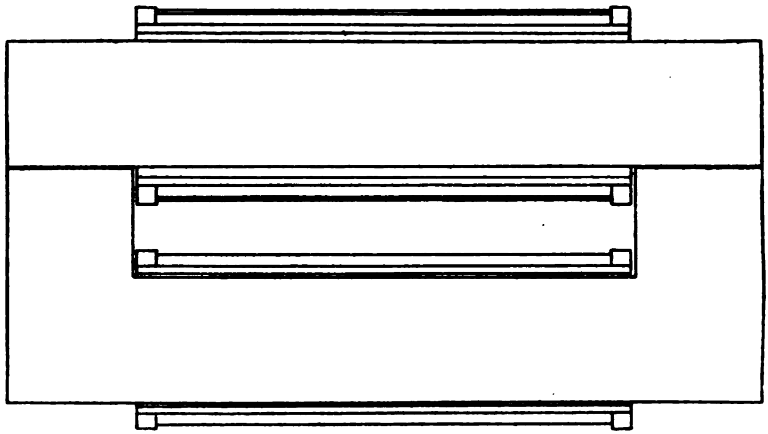

FIG. 2.
Scale—4 inches to the foot.

instrument is calibrated once for all by making the sample and the fixed part, or yoke, of the magnetic circuit out of the same quality of plates, measuring the loss of power at different inductions, and apportioning the losses between the yoke and sample according to their weights. When testing other samples the total loss is measured by the wattmeter, and from this is deducted that portion of the loss which is occasioned by the iron which forms part of the instrument, the remainder being the loss in the sample. A correction must be made for the loss of power resulting from the ohmic resistance of the two coils, but this is exceedingly small. The induction is found from the E.M.F. applied to the coils and the frequency. In order to have a wide range of induction, and yet keep the measurements of current and E.M.F. within the limits most convenient for the instruments at hand, the coils are subdivided, and suitable terminals are provided. The resistance of the joints between the sample and the yoke is immaterial, as it influences only the current, but not the power.

The upper curve in Fig. 3 shows average results obtained in testing samples of plates furnished by several different suppliers

of transformer iron. I say advisedly "suppliers," and not makers, Mr. Kapp. because iron merchants are, as a rule, disinclined to give the name

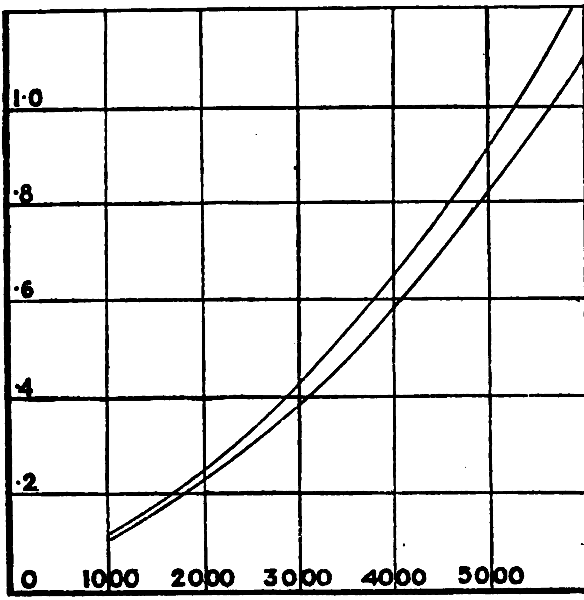

Fig. 3.

of the maker. In fact, I have had a case in which two samples supplied by rival merchants gave precisely the same curve, and on making inquiries I found that the iron came indeed from the same maker, but was sold under different names. The lower curve in Fig. 3 shows the results obtained with the best sample I ever tested. As it is not my purpose, and as it would indeed be improper to advertise any particular maker in a paper of this kind, I trust you will not expect me to give his name. The curves are, for convenience in use, plotted under the supposition that the frequency is 100. The abscissæ give induction, and the ordinates loss of power in watts per pound of iron. The thickness of plates varied between 10 and 13 mils. Within these limits I believe that the thickness has only a very small influence on the loss—at any rate, I have not been able to detect any such influence; and this confirms an admirable investigation by Professor Ewing in which he showed, on theoretical grounds, that

Mr. Kapp a reduction of thickness below about 13 mils is of no advantage. It is, of course, quite easy to test transformer plates by taking a known weight of stampings and making them up in a transformer with only one coil (preferably a low-pressure coil). If the same coil be always used for this purpose, the results will be perfectly reliable. The method is, however, tedious when a number of samples has to be tested, as time is wasted in building up and taking to pieces again the plates between each set of tests. With my testing machine all the samples can be prepared beforehand, and slipped in quickly one after another, so that the whole series of tests can be performed under the same conditions and by the same men. The facility with which samples can be changed is also of value if it should be necessary to verify any doubtful point in the curve obtained in a previous test.

There is another and very obvious method of testing transformer iron, and that consists in making up a complete transformer with the sample plates to be tested. Apart from the waste of labour entailed if the iron should turn out bad, this method is very uncertain. The reason for this uncertainty is that we test, not the iron alone, but the complete transformer, and we are thus left in doubt as to how much of the measured loss is really due to the iron. Theoretically the whole loss is due to the iron, but in practice this is seldom the case. When testing a transformer immediately it is completed, and again after some weeks during which it has been regularly at work, you will find that its losses have become less. This I believe to be due to the coils having become thoroughly dry, and their insulation higher. A very small electrical leak in the high-pressure winding may easily lead to a waste of power, which, although small in itself, and not capable of doing any damage, is still appreciable when compared with the true iron loss. Take, for instance, a 4-kilowatt transformer wound for 2,000 volts. Its iron loss would be about 2 per cent., or, say, 80 watts. Suppose, on testing this transformer, you find that the loss is not 80, but 100 watts. You might then conclude that the iron has 25 per cent. more loss than it ought to have, and you would condemn

the sample. This might, however, be an unjust verdict. The extra 20 watts measured might very well be due to a general leakage of current across the turns of the high-pressure coil. The leakage surface is large, and the pressure is large, so that the current-density of the leak is very small, and no damage will be done. The leak vanishes as the transformer gets dry, and thus may be explained the curious fact that transformers get better after use. The moral of this is that to do justice to a transformer the final test should only be taken after it has been at work for some time. Mr. Kapp.

In conclusion, I wish to express my thanks to Messrs. Johnson & Phillips for the loan of the testing machines here exhibited.

The PRESIDENT: We have heard a very interesting paper, and, as it is on magnetism, I am sure we should like to hear what Professor Hughes has to say on the subject. The President.

Professor D. E. HUGHES: Mr. President,—I thank you for having so kindly asked me to make a few remarks in relation to Mr. Kapp's admirable paper; but I feel that, whilst I have had a large experience with testing iron for the low magnetic force used in the electro-magnets for telegraphy, I have not had any wide experience with the very high magnetic power that is used to-day in dynamos and transformers. Professor Hughes.

The principle of measuring the holding power of an electro-magnet upon its armature is one that I have employed in my printing telegraph instrument for the last 30 years. I thus know that this method can be rendered exceedingly sensitive, and made to record the slightest change in the magnetic state of the electro-magnet; but at the same time I know that great care has to be taken that the armature shall rest in contact with the core in a perfectly invariable condition, else a great change in the amount of force required to separate the armature is observed.

In my telegraph instrument these conditions are easily fulfilled, but I fear that in Mr. Kapp's arrangements the armature would with great difficulty be brought exactly in the same condition as to contact that it had in a preceding test.

Mr. Kapp has no doubt met with this difficulty, and probably

rofessor ughes. vanquished it; but I should like to ask him what precautions he employs to ensure an absolute identical contact at each trial of different specimens.

I will only add my warmest appreciation of Mr. Kapp's paper, and express my thanks to him for having brought it before our Society.

rofessor hompson Professor SILVANUS P. THOMPSON: Mr. Kapp has done me the honour of referring to my permeameter that I devised some four or five years ago. When I described it first it was very primitive, and the second form of instrument that was made by Messrs. Nalder Bros. was very much better. I would remark that, while it is quite true that we may make corrections for various sources of possible error, such as the magnetic reluctance of other parts of the apparatus than the part under measurement, yet still it seems better to me that when instruments of this kind have to be designed, they should be designed so as to avoid all sources of subsequent correction. I am justified in making the remark by what one knows about electrical testing instruments. For instance, in the design of the metre bridge we take care that all the auxiliary conductors and copper work shall be very thick and highly conducting compared with the wire which is stretched along, and which is to serve as our standard resistance; and we take care that all the contacts that are made should have as slight a resistance as possible, in order that their quantities which might be applied as corrections should be for all practical purposes negligible. That was my idea in the second form of permeameter that I made, wherein the cross section of the mass of iron surrounding the coil and plunger was in my instrument 200 times as great in cross section as the sample which served as plunger; so that one might entirely neglect any correction for the ampere-turns necessary to send the magnetism through the other parts. Then my plunger, which itself was the test piece—I had no auxiliary plunger—was made longer and thinner in proportion than is the case in Mr. Kapp's instrument; the length being for the purpose of eliminating the error due to possible defective contact. For if one chooses to work with a long, thin piece, the magnetic reluctance of which is large, then

we spend a large number of ampere-turns in magnetising it, and any additional number of ampere-turns required to push the magnetism through the little air gap at the end is small, and may be neglected. My instrument, I ought to say in all fairness, was directly suggested to me by the researches of Dr. Hopkinson. The members will remember that in Dr. Hopkinson's method of testing the magnetic qualities of iron he had a large massive block of soft iron of rectangular shape, with a rectangular hole slotted out, very much like Fig. 1, only more massive, and that the test pieces to be examined were two bars that met in the middle. The magnetising coil filling up the rectangular middle hole was in two parts, and a small exploring coil could be introduced into it between them. The two test pieces were made to touch one another, and then one of the two was pulled out. Then the exploring coil flew out, being pulled out sideways by a piece of india-rubber, and in that way cut across all the magnetic lines going through the two test pieces. It occurred to me, in looking at this apparatus of Dr. Hopkinson's, that the effect which he has sought to measure when pulling the two test pieces apart, and measuring the flow of magnetic lines by the little exploring coil and the galvanometer, might be equally well measured by the pull of one test piece on the other. And having got as far as measuring the pull of one test piece on the other, I then said to myself, Why should you take the trouble to make two test pieces and face them both up in the middle, when you get exactly the same pull by having one test piece going the whole length and merely pulling it off from contact against the yoke? I did not adopt this construction (which has been criticised by Professor Ewing), having a contact surface at the end of the test piece instead of between the two test pieces, without investigating the matter to see whether it did really make much difference. Take the two test pieces, and make one stick up against the yoke at one end, and the other against the second test piece right in the middle of the coil.

Professor Thompson.

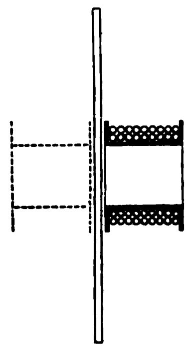

Fig. 1.

Professor Thompson.

Then tug at the second test piece: sometimes the iron will part in the middle between the two test pieces, and sometimes at the other end between the further test piece and the yoke. You never can tell which will happen, so that there is not much difference between the two attractions, the overcoming of which measures the square of the number of magnetic lines per square centimetre. Consequently the simpler method which I finally adopted is quite adequate for its purpose.

I congratulate Mr. Kapp on having given us such an excellent instrument for measuring the magnetic properties of sheet iron. It is a pity, perhaps, one has to cut the sheets up into strips in order to do this, but it does not waste very much iron. And here, again, I would ask Mr. Kapp to take my criticism kindly, if I venture to say that the same criticism might be passed on this instrument—that the other piece of iron which is not under test, having about the same cross section as the piece of iron which is, the corrections that have to be applied, or the allowance that has to be made for the ampere-turns necessary to magnetise the rest of the circuit, is a quantity of the same order as the ampere-turns required to magnetise the test piece itself. If the cross section of the other part could be enlarged very much indeed, I think it would simplify matters, especially as the hysteresis question comes in to complicate calculation. The two curves for the two kinds of iron used cannot possibly be the same, and at high inductions may be very different indeed, so that corrections to be made for magnetisation at one stage of saturation, will not be the same as the corrections made for magnetisation at another stage of saturation. Whereas, if the other iron than that under test were made of very large cross section, so that it never came very near saturation, any correction made in it would be much more likely to be the true one for all degrees of saturation. Now let me add another thing: it is a most interesting point, one on which at present I am engaged in a research, which I had meant to publish later on. Its bearing on the design of permeameters is obvious. It is on the behaviour of masses of iron such as are used in the first instrument here, and in my permeameter, for the purpose of serving as yokes in an instrument having no magnetic

resistance. I have arrived at the most interesting point of view that a large sheet of iron—so large as to act practically as an infinite sheet—so large, say, as 5 or 6 feet in each direction—acts towards all things that may be placed in front of it as a magnetic mirror, giving, however, negative images only, not positive. I had better explain by a rough sketch what I mean. Suppose there to be a large sheet of good soft iron. Then let there be placed anywhere against the side of it a hollow bobbin with wires wound upon it. Suppose a current circulating round that coil, producing a certain magnetising effect. If no sheet iron were there, the magnetising forces all round this coil, through the interior of it, and outside will have certain values. Now put the *sheet* of iron there, and you will find that the effect of having that large sheet of iron there is precisely the same as though the sheet of iron were absent and the coil were continued behind to double the length—that is to say, as though the coil and its "image" were both at work. A little exploring coil, for instance, placed hard up against the iron will show that the effect of the iron is simply to double the action of the magetising coil. Take away the iron and the effect falls to one half. Put the second coil there with an equal number of ampere-turns flowing round it, and it acts precisely as the "image" of the first coil had done, and not only when they are hard up against the iron, but in various other positions. The sheet of iron must not be very thin; it must be thick enough. Suppose we have the sheet of iron at one end of the coil, and we place a second sheet on the other end of the coil. Professor Thompson.

We get the same problem, optically, as if we put a candle between two mirrors. In the optical case we get an endless row of candles in both directions, and here we get an endless row of coils in both directions—that is to say, the coil becomes endless; in fact, we arrive at the expression that the ampere-turns in this coil, multiplied by 4 π, divided by 10, and divided by the length in centimetres, is the true expression for the intensity of the magnetic force along the axis of the magnetising coil, as it is along an infinitely long solenoid. This mode of treating permeameter problems might be continued a great deal further.

Professor Thompson.

I should like to suggest to Mr. Kapp whether he cannot suggest some way of getting at the magnetic properties of iron not in a rod or in a sheet, but in a block—a cubic yard of iron, for instance, presenting simply a flat surface. It ought to be possible. I am going to make a suggestion to him upon it. Let there be a thin strip of ebonite (Fig. 2). Drill in that two round holes; have two small coils, one to receive the current, the other to give current to galvanometer —a sort of thin transformer, if you like, with the coils not superposed. Lay these on the block iron; turn on the magnetising current. The number of magnetic lines that will come up through that second hole from the iron will depend on the goodness of the iron below. But unfortunately we have to consider the whole magnetic circuit, and that will not be made perfect enough without having another block of iron placed on the top and leaving a thin layer between. The thickness of the small air gap depends on the thickness of ebonite strip. It may be very thin, and the coils very large, in order that we may get rid of the error arising from the air gap. In some such way we might get a method of measuring the permeability of iron in the mass.

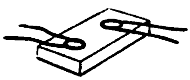

Fig. 2.

Mr. Steele.

Mr. L. J. Steele: A long series of tests have been made under my charge at Messrs. Johnson & Phillips's works on the magnetic properties of steel and iron used in the manufacture of dynamos and transformers, and I may safely say that the results obtained by the methods and instruments described by Mr. Kapp have yielded very accurate and consistent results; a very short time being required for making the tests.

With regard to the permeameter, just one caution should be taken in obtaining material for making a sample bar. If in the case of cast iron or cast steel a small bar is cast, only sufficiently large for turning to the required diameter, the results obtained on testing the sample may be considerably worse than the results obtained in an actual test of the dynamo. This is due to the fact that the skin of the casting has not been all turned away. Therefore it is necessary to obtain a sample of sufficient—of considerably larger—diameter than that eventually required. The

samples themselves, as Mr. Kapp has pointed out, must be carefully faced at one end. This takes some time, and, as Professor Hughes has remarked, an error may be made, unless this sample bears evenly against the plunger, and is placed in the correct position every time. I suggest getting over this difficulty by using a small iron cap carefully faced at the end, which would be used for every test. This would effect a considerable saving of time in having to face up every sample, and the results would be more consistent; that is to say, the same face would be used for every sample tested. Although this instrument is not designed for receiving this cap, I do not think it would be a difficult matter to adapt it. Mr. Steele.

The testing machine for transformer plates has proved of immense value in testing samples of sheet iron for transformer purposes. To make up the transformer and then test it is a risky proceeding, for if the iron turns out bad the transformer may be of little use for commercial purposes. A sample for the machine can be made up, the plate tested, and the curve obtained in about two hours; whereas, if the transformer were built, it would take a much longer time. The three-voltmeter tests were first used for measuring the losses in the iron: the tests were accurate enough, but the results required laborious working out. The wattmeter now used requires much less work, and yields equally accurate results, quite consistent with the old voltmeter test. The facility in making these tests has already helped in a large degree to reduce the losses in the transformers, and placed the makers in a position to offer guarantees of efficiencies which are quite high as compared with those of a year or 18 months ago.

KAPP TRANSFORMERS.
100 *Frequency*.

Size.	Percentage Iron Loss.	Full-Load Efficiency.
3-kilowatt	1·74	96·4
6-kilowatt	1·34	96·9
12-kilowatt	1·13	97·25
20-kilowatt	0·95	97·4

Mr. Steele. The list before you gives the full-load efficiency and percentage iron loss for four standard sizes. You see the iron loss in a 20-kilowatt transformer is only 93 per cent., and the full-load efficiency is 97·4 per cent., which I think you will all agree is very good. The leakage in the high-pressure coil which Mr. Kapp has referred to has been a source of considerable trouble. The transformers were tested, and the iron proved apparently bad; at last it was found, through an actual breakdown in one transformer, that the great loss was due to electrical leakage, and not to bad iron. This can be prevented by carefully baking the transformer, which is always done before the transformers are sent away from the works. The tests, however, cannot be made before the transformers have been baked for several days, which is most effectively done by sending a heavy current through the windings, thus drying the transformer in a quicker time. It may, however, be most inconvenient to wait several days before the transformer is ready, and for this reason the method of testing iron in the instrument possesses a great advantage. There may be a fault in a transformer which is quite local, due to a short-circuit or partial short-circuit of the primary or secondary coils. When the transformer is magnetised the open-circuit current and the watts will be abnormally high. It is difficult in such a case to localise the fault. A method I have found to answer admirably is to hold a small rod of iron, say 2 or 3 inches long, loosely in one's hand, or to suspend it horizontally, and move it in the direction of the leakage line of the transformer. If there are any turns short-circuited, the magnetic leakage produced at that place will cause this piece of iron to suddenly dip and be directed towards the short-circuited coils. The position of the fault is then localised, but the difficulty may be to find whether the fault is in the primary or the secondary coil. In a Kapp transformer the coils may be easily slipped off and an alternating current sent through each. A repetition of the above experiment will at once show clearly where the fault exists.

Apart from the use of such instruments to manufacturers of dynamos and transformers, I feel sure that makers and suppliers of iron will acknowledge the benefit they have derived from the

numerous tests sent to them of their samples, whether good or bad. Mr. Steele

Professor J. A. FLEMING: The question which Mr. Kapp has brought before our notice is one that none of us can deny is of exceedingly great importance. It is of importance from the point of view of the manufacturer of transformers, and it is also important from the point of view of those whom the Acts of Parliament call "undertakers." Mr. Kapp has approached the subject chiefly from the point of view of those who manufacture transformers; and I am sure we are only too happy to have Mr. Kapp, with his large experience in the manufacture of transformers, bring this before us, because he has succeeded in producing a very excellent one. I am not sure that I altogether agree, however, with some of Mr. Kapp's conclusions. Before one has had the opportunity of working with a machine of this kind, and actually putting its results in comparison with results in practice, one would naturally hesitate very much indeed to criticise, and I should therefore prefer to put the few remarks I have to make in the form of questions rather than statements. Professor Fleming.

Everyone must admit that of course what we desire to know about a transformer is the performance of the instrument when complete; and that merely to have the determination of the performance of a part of it, and from that to deduce the whole, is not necessarily always to get a satisfactory result. I am not sure that it is always certain that, unless you test iron in the form in which it is going to be actually used, you are able, from experiments on small samples, to deduce what is the total loss in the iron. In the first place, although laminating the iron below the thickness of 10 to 13 mils certainly does eliminate the eddy-currents in some cases, it is not true that there are, may be, no eddy losses in the completed transformer, because the form which the transformer may have may be such as to produce eddy-currents circulating in the plane of the strips. I may take, as an instance, one which would be an extremely bad transformer, to illustrate my point. Imagine a strip of iron an inch or two wide, wound up edgeways. Put on a couple of coils, primary and secondary. Although you might deduce

Professor Fleming.

the loss at no load in the iron under those conditions, yet, nevertheless, when you worked that transformer in full load you would have considerable magnetic leakage, and you would have lines of induction which would sweep backwards and forwards through the iron perpendicular to the sheets; and the moving about of that induction would create eddy-currents in the plate, however thin it may be. It is not, as it seems to me, therefore, necessarily certain, because you find the loss in a small specimen of iron made up in a particular way, that you can deduce the value of the loss when made up into a particular form of transformer. Then there is the additional loss which may ensue if the transformer is not dry. That certainly is in some cases very marked. There are great discrepancies sometimes between transformers tested at different times and different places, which can be accounted for by the assumption that the transformers have been tested in different degrees of dryness. This loss is, perhaps, not altogether simple loss between the coils due to power taken up in evaporating moisture from the winding or insulation, but may be due to the increase of eddy-current loss, if the paper between the plates, or the plates, has moisture in it. And certainly it is necessary, in making practical tests, to be certain that the transformer has been properly dried; and it is sometimes difficult with a good transformer to do that in the ordinary way, because you cannot, without a very large expenditure of power, and working it for some time at full load, raise the transformer to a sufficiently high temperature to drive out this moisture from the paper or insulation. I think that in all cases the cores of transformers ought to be brought to a fairly high temperature before they are wound, and then, of course, care must be taken that they are not in any way spoilt before they are tested.

Another thing which is also important to bear in mind, I think—although one must hesitate in speaking too confidently of it at the present time—is that the loss in the iron seems to be dependent to some extent upon the form of the E.M.F. curve. I raised the question recently with Mr. Blathy whether certain tests made with a particular transformer in two places which were discordant with one another could in any way depend upon

the form of the E.M.F. curve. Mr. Blathy told me he had tried the experiment of taking the same transformer and testing it upon a machine which gave, approximately, a true sine E.M.F. curve, and then trying it upon another machine in which it was known that the form of the E.M.F. curve was different from a simple sine curve, and the result was that the transformer tested on the simple sine curve gave a much higher loss than the other case. That shows that in cases where one has to specify exactly the losses in transformers it may become necessary to specify exactly the kind of machine on which it is tested. Professor Fleming.

But although I think Mr. Kapp's instrument might become useful, one would like an opportunity of comparing the results of testing the samples of iron by this machine, and then making it up into a transformer and letting them be tested again. I should like to ask the author, in his reply, if he could tell us whether he has tested a sample of iron by this machine and then afterwards made it up into a transformer and tested it again, and found out if the results given really correspond with the results of the predetermination of the iron. But, at any rate, Mr. Kapp has certainly moved in the right direction in turning his attention to some of the means by which the qualities of the iron can be predetermined, and in which the expense may be saved by making up these transformers on a scale of 12 inches to the foot before being able to ascertain what it is that the iron really does do.

Mr. C. P. Sparks: I also wish to ask the author very much the same question as Dr. Fleming has asked—that is, when a test is made on a small bar, as in the apparatus shown in Fig. 1, whether, after it has been worked, the results obtained in practice are anything like the results obtained during the experiment, because it has to go through the operation of being drawn out, it is forged to a greater extent than an ordinary magnet block, and there is a chance of it being better annealed. After you have worked up the sample it has to be turned in a lathe, and this has a different effect on the material, to the machining of a large block. Under these circumstances one would imagine the results obtained would differ in the experimental bar from those obtained when the iron was made up in the form Mr. Sparks.

Mr. Sparks. of a dynamo field. With reference to transformer iron, I have made a great many experiments on samples: the chief difficulty seems to be the great variation met with in any parcel of sheets. If you take even one sheet and make experiments on smaller quantities than the author has shown, there seems to be an enormous difference between the results of different parts of the same sheet. Then, again, if you take a large quantity—a number of tons—you find marked differences in one ton over another; and, further, it is almost impossible to get two batches of iron made up at different times to give anything like corresponding results, making it impossible for makers of transformers to guarantee efficiency without having a large margin in hand. If they guarantee down to the last limit, they are very often caught within one or two per cent. I should like to know whether the results the author has obtained on small samples agree within a small percentage when made up into transformers.

(*Communicated.*)—As the hysteresis in any sample tested depends not only on the chemical composition, but also on process of manufacture it goes through, it would be interesting to know if the author has made any tests with his apparatus to see whether change takes place after a sample has been subjected to reversals of magnetism in the same manner as the core of a transformer, with a view of showing whether the hysteresis loss in a transformer core is likely to remain constant, or whether it increases after it has been in use for a year or two.

Professor Perry. Professor J. PERRY: At the beginning of this discussion I thought I had something to say, but after Professor Hughes and Dr. Thompson had spoken I felt I had very little to say. I should like, however, to suggest to Dr. Fleming that, instead of going to large works like the Elswick Works for samples of pure iron, as he wants only a small sample, he will find it much better to apply to one of the manufacturers of cast steel of Sheffield, who make the most expensive steel from the purest Swedish charcoal iron; otherwise his experiments will probably be made, not on pure iron, but on Siemens steel, which is now nearly universally sold as charcoal iron. Let me also say to Dr. Fleming and Mr. Kapp, as I was probably the first to speak of the

way in which the overtones are filtered out and the pure sine functional current is produced, that when I made the explanation in this room I was speaking of currents passing through machines and through coils with self-induction in them, when you certainly have the filtering-out process; but there is no such thing in a transformer. The secondary current from a transformer is almost a perfect image of the primary current with the fundamental and overtones in exactly the same proportions as in the primary current. I think that Dr. Thompson's suggestion for measuring the magnetic quality of iron when in bulk is not an altogether good one. To prove this, I will use the very beautiful weapon that he has put into our hands this very night. Here are two of the coils he spoke of, and I will take them as large and thin as he pleases. Instead of his two iron plates, take what is much more perfect for his theory—two of Mr. Kapp's blocks. Now what he told us comes simply to this—that there is no magnetic resistance in the iron blocks; the induction there is always weak, and, however great may be your ampere-turns, you have no magnetic resistance in the iron, or sign of hysteresis. In fact, it is air resistance only you are testing. It is interesting to know from Mr. Steele that the "divining rod" is not pure quackery. His bar of iron is the first really authentic divining rod, and he uses it in seeking for a leak, seeking for places of dampness or wetness. I also wanted to say to the author what Dr. Thompson has already said—that the idea in the second, or hysteresis, instrument of having a great permanent mass of iron of small resistance, just as in the first instrument, must here also lead to smaller errors of measurement. I would put my reason in the following way:—Your specimen plates being of smaller section, and the permanent part of your instrument of very much larger section [*the speaker sketched on the blackboard the permanent part, shaped like an incomplete transformer, the specimen completing the magnetic circuit*], there is almost no hysteresis loss in the permanent part as compared with the specimen. This must be evident when we recollect that hysteresis loss per cubic centimetre is proportional to something between the square and the 1·6th power of the maximum induction.

Professor Perry.

Professor Perry.

Only one word with regard to the very just remark made by Professor Hughes. The reason why bad fitting produces such very evil results may not be known to everybody, although it is probably fairly well known to those who have made steel permanent magnets. If you want great lifting power in a permanent magnet, all you have to do is to have your areas of contact between the iron armature and the two poles very small. The lifting power is nearly inversely proportional to the area of each pole. One ought, I suppose, to assume that everybody knows that fact, but only this very day I found that two of my best students did not know it. The point is this: On every square centimetre of area of contact the actual force of attraction is proportional to the square of the induction. So that, if the same total induction (or even not quite the same) passes through a smaller area, there is a greater intensity of induction; and without troubling you with even this easy kind of mathematics, I think it must be evident that the total force of attraction is increased. In connection with this, I may mention another interesting matter. Some of you may have been astonished at certain results of mine, published some years ago, of the permanent magnetic induction that could exist in a steel magnet having no armature. I think I gave results something like three times as great as anybody else had ever obtained. But anybody who has gone into the matter must see that you can get an enormous induction if you properly shape your magnet. All you have to do is to have a magnet of very small carrying power—that is, with poles of great area—for here your magnetic air resistance is always small. I need hardly say that Messrs. Johnson & Phillips are not likely to have bad fitting between two pieces of iron; but if you have surfaces not perfectly flat, you have small areas of contact and greater forces.

I would like to remind Dr. Thompson that it was Mr. Bidwell who first measured induction by drawing asunder two pieces of iron; that is, he had the two semicircular halves of an anchor ring, with a coil on one of them, and he dragged one from the other. To bring the matter to Dr. Thompson's recollection, I would remind him of the interesting discussion that occurred at

the Royal Society between Lord Rayleigh and Lord Kelvin as to whether the method was correct or not, and what the influence of the coil was. Professor Perry.

Mr. W. M. MORDEY: I must congratulate the author on the practical form of his instruments. Of the two, it seems probable that the bar testing instrument will be most generally useful. I should like to see some of the results obtained with it, showing what degree of accuracy is attainable—this is apparently sufficient for workshop purposes. If so, it will be a great improvement over ballistic galvanometers and all other instrumental methods, which are out of place in workshops. The objection to traction methods has always been that surface contacts have varied. If this objection does not hold in this case, I for one will be very glad to follow the example of the author and of Professor Thompson, and use such an instrument; it is the very simplest form of magnet tester, and therefore should be the most scientific. Mr. Mordey.

I should like to ask the author whether he has experimented with this apparatus on the effect of time in changing the carrying power of the bars. Are the results the same if the observations are taken in rapid succession as when taken slowly? I alluded to this point in a discussion here some time ago, and drew attention to some very interesting observations by Lord Elphinstone and Mr. Vincent, contained in a Royal Society paper read in 1878,* showing that an enormous increase in lifting power could be got by very slowly increasing the weights during a number of hours. By taking many hours over an experiment they could get a magnet to hold ten times as much with no exciting current, as was sufficient to break the keeper away if they made the experiment quickly and with the exciting current on. Of course we have now a great deal of information of a reliable character, by Ewing mainly, on retentiveness, which the author has no doubt considered. I wish him, therefore, to tell us what precautions, if any, are required to be observed on this account in using his instrument.

There is another point that is interesting to dynamo builders,

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* *Journal of the Institution*, vol. xxi., p. 738.

Mr. Mordey. and that is the unfortunate fact that small testing bars are not always true samples of bulk. One often finds that iron differs a great deal in the same forging. I heard only the other day of a curious instance of this. The armature of a drum machine was always pulled to one end, and there was, in consequence, heating of one of the bearings. The armature was central, and it was level, and there did not seem to be any reason for the difficulty. Upon investigation, it was found there was such a difference in the quality of the iron between one end of the machine and the other that there was a considerable pull exerted in one direction.

The particular part of the author's paper that I am most interested in is that dealing with transformer iron, and I quite agree with the remark which has fallen from Dr. Fleming, that there is really at this moment in connection with the building of electrical apparatus no more important question than that of getting good magnetic iron. We are all interested in it. Personally, in connection with the Brush Company, I have had a great deal of trouble indeed on account of the inability of iron manufacturers to supply iron of anything like even quality; and the statement which the author has made that iron makers are now offering iron that will conform to definite specification as to watts per lb., is probably the result of the efforts made by me on behalf of the Brush Company to obtain iron in that way. As a matter of fact, we now order and obtain all our iron to a specification of that sort; and, as the specification is public property, I see no reason why I should not mention the terms of it. The standard magnetisation is taken at 2,500 lines per square centimetre—that is, 16,125 lines per square inch—and the loss at 100 periods is 0·38 of a watt per lb., or 1·14 H.P. per ton. Now that is a standard that is not set at all too high; that is to say, it is usually easily worked to. Iron is obtained having a loss as low as 0·25 to 0·28 of a watt per lb.; and, on the other hand, it varies 60 per cent. above the standard—even out of the same batch of iron. Now that is often a very awkward circumstance for all who have to use it. It is not to the interest of any one firm, or of any one individual in particular, to keep information that he has on this subject to himself. The interests of all of us are identical

Mr. Mordey.

in this matter, and we should all do everything in our power to encourage iron makers to face this subject—it is a very important subject indeed—and to endeavour to ascertain the reasons why iron sheets of good quality in other respects vary so enormously. They are facing it after a fashion, but the iron people do not understand electrical and magnetic quantities at all. They look at the thing as a kind of sacred mystery, and until lately they would shrug their shoulders when we asked them to give us iron of any definite quality. The specification that we have now forced on the trade is being worked to.

As to the effect of chemical composition on magnetic quality, so far as my experience goes, chemical analysis is absolutely no guide whatever to the quality of iron. I do not mean to say that you will not get very bad results from very impure iron, but I mean that you may get very pure iron indeed—iron almost exactly the same in analysis—which will vary 60 or 70 per cent. in the hysteresis loss. This appears to indicate that the question is a physical question—a question of condition rather than of chemical composition.

The author has done us a service by bringing his apparatus before us. The criticism that I would make is one that has already been made. It does not test the whole transformer; there are parts of the apparatus—parts of the iron circuit—that are always in use, and to that extent, unless those parts are so made that the effect in them is negligible, I think the apparatus can be improved; and it may be improved in the way that the author has himself suggested at the end of his paper, by always testing as in the actual transformers. This is not quite a fair criticism, for his object was specially to be able to test sheets in their simplest form. I do not mean to say that it is necessary to make iron up into actual transformers, but that samples should be tested in suitable testing coils. That gets rid of the difficulty of leakage due to moisture in the coils. It is a method we have used for some years, and it gives us no trouble at all. We never consider any tests of really final value unless they are made actually out of the stampings from which transformers have to be made. This is not a very great objection, as the makers always have means for producing stampings of various shapes and sizes.

Mr. Mordey. The importance of testing transformer iron can be realised, I think, pretty clearly when one considers the value of the power that is wasted in transformers. The value of the wasted power may be taken in this way—it is a figure that is easy to remember: If you take power at 1d. per H.P. per hour—I do not mean to say that is a figure which everybody will accept, but it is a figure easily carried in one's head—then a watt continuously expended costs you 1s. a year. At one penny for one H.P.-hour, one watt for one year costs one shilling. You see, therefore, that, as one watt is only 1-746th of a H.P., it becomes very important indeed to be as economical as you possibly can with regard to the loss in transformers.

I think that the engineers of central stations are beginning to appreciate that it is true economy to pay highly for their transformers—that is to say, to get the very best transformers that can be obtained.

Another point: I would like to know what arrangement is made in connection with this apparatus—and I would ask the author to supply the information—for showing how the power-factor varies in different samples. It is an extremely curious thing the variation of the power-factor in connection with iron under alternating currents. It may vary all the way from 0·6 to 0·9, while the hysteresis may be practically the same. The power-factor may vary very considerably, but as a rule it does not vary more than from 0·75 to 0·85; but it may vary through the limits I have mentioned, and that means that any test taken only of current is valueless. Transformers must be tested, therefore, with a wattmeter. It is extremely interesting to endeavour to find what is the reason of this variation in the power-factor of transformers at no load. As far as I know, there is no information at all at our service on that point. At one time I thought that it had to do with the electrical resistance of the iron, but from some tests I do not find any connection there. It is a very curious fact, and it is an important one. It affects the central station engineers to a certain extent in the outgoing current in the daytime: the current may vary while the power may not vary. And, of course, the output of any

given plant depends almost entirely upon the current that is drawn from it. These are points of detail, and I would like the author to tell us in his reply how he has dealt with them in the apparatus before us. I am rather surprised to hear that he finds very little difficulty with the contacts in these testing apparatus. I find a great deal of difficulty with the contacts; and in the specification to which I alluded just now we make it a rule to make that specification apply to the particular form in which we use the iron. We take no note of anything else. I do not mean, of course, that the loss for the same magnetisation is not constant for the same quality of iron; but as the iron has to be used in certain transformers of certain types, therefore the test is made applicable to that type of stamping. Mr. Mordey.

Mr. H. RAVENSHAW: I consider the importance of testing armature iron is as great as that of testing transformer iron. The losses are larger in proportion in large dynamos than in small ones. Iron varies very much indeed, and it is necessary to test the iron used as frequently as possible. The difficulty is to get it done rapidly; a simple form of apparatus like that of Mr. Kapp is of the greatest value for the purpose. A case lately came under my notice where the hysteresis losses in iron were exactly twice in bulk what they were in the samples. Mr. Ravenshaw.

The PRESIDENT: I wish to make a few remarks now, so as to give the author the opportunity of answering. I will be very brief, as the hour is already so late. The author says in his paper that the method devised by Dr. Hopkinson and Professor Ewing "gives the most accurate results; but the very perfection "of these methods forms a drawback to their adoption in engineer-"ing works, where highly trained experimenters cannot be found." Then in another place in his paper he says, "The sample consists "of a bar accurately turned, and faced at the lower end." The President.

From the remarks of Professor Hughes and Mr. Mordey you have already learned that really the author, by his method, simply changes the nature of the difficulty from an electrical to a mechanical one; because the production of these beautifully turned bars, although possible, takes a long time, and requires a good deal of mechanical skill.

The President. Now I just want to show you the way in which the magnetic qualities of iron are tested at Woolwich, and you will at once see that it is a very much simpler and a very much safer method. It is based upon Professor Ewing's experiments, and the apparatus consists of a solenoid formed by a coil wound on a split brass tube about 3 feet long and about $\frac{3}{4}$ inch in diameter. The solenoid is joined up in circuit with a specially constructed rheostat, by means of which the resistance can be varied by small abrupt steps of unit difference in power, and with a battery which gives about 10 volts; a double current key is also inserted for reversals. Surrounding the centre of the solenoid there is an exploring coil of any requisite number of turns suitable to give a convenient deflection on the ballistic galvanometer in circuit with it. It may be here remarked that for test pieces of small diameter an ordinary damped galvanometer suffices, and a ballistic needle may be dispensed with. The calibration of the galvanometer is effected in the usual way by discharging through it a condenser of known capacity, charged to a known potential.

For testing permeability, the test pieces cut from the iron are made of such length that the correction due to their ends may be negligible; but for determinations of hysteresis the test pieces may be much shorter, the length being not more than from 60 to 100 times the diameter, without making any appreciable difference in the area of the cycle, though there will be a difference in the magnetising current required.

The comparison of the iron is effected by calculating, by analytical methods, the areas of the hysteresis lozenges for the several sorts. The iron test piece is placed inside the solenoid, and the current sent through the latter is varied by the help of the rheostat, as previously explained; the kicks which the galvanometer needle gives each time the resistance is altered are then plotted down.

Now you see there is no fitting in this whatever, and there is a very curious thing—viz., that if you take a piece of iron which is only half the length, and complete the hysteresis curve, you will get a lozenge which is tilted over with reference to the axes of co-ordinates, but you will find that the area of

this latter hysteresis curve is exactly the same as the area of the former one obtained with the longer test piece, provided they are both taken from the same piece of iron. It is therefore unnecessary to work our samples accurately to the same size when we want to compare them; we have only to cut the piece of iron off the block which we want to test, put it into the solenoid, and take a set of readings—which one man can do in a quarter of an hour—and we know exactly what quality of iron we have before us. The President.

I may mention incidentally that in the hundreds of comparisons of test pieces which have been made at Woolwich, we have found that Steinmetz's law of the 1·6th power is practically correct.

Mr. G. KAPP, in reply: Professor Hughes has really sounded the key-note of the only important objection to this instrument, and that is, the difficulty of getting a true surface, so that you can rely upon its contact. I need not deal with all the little details of the instrument, but I may say that the design is the outcome of a prolonged study, and has grown out of trying to overcome one difficulty after another. To ensure good contact, the instrument is designed so that the sample is automatically centred. That is the object of the ferrule. Further, to test the contact, all you need to do is to put a little red lead on the end face, put the sample in, bring up the plunger, and turn it. Then you take the sample out and see whether the surface is equally covered with red lead. Any fitter knows how to make this test. It is thus perfectly easy to get the surface practically true. Moreover, you must not forget that this instrument is not intended for testing inductions of 2,000 or 3,000, where a reduction of surface would introduce a serious error; it is intended for testing inductions above 10,000, and then it matters less if the surfaces should not lie on quite flat. I have purposely spoiled a sample in order to test that point. I have taken one of the samples which has gone through the instrument, and, after filing a small piece off the edge, tested it again. The result was what one would expect—namely, that for low magnetising forces the induction came out too high; but the Mr. Kapp.

Mr. Kapp. error would become less as the magnetising force was increased, and vanish almost completely in the region which is most important for practical purposes. At high inductions the magnetic resistance of the sample is so great, as compared with any possible air resistance due to imperfect contact, that the latter can have but an infinitesimal effect on the correctness of the result. I admit the existence of the difficulty, but I claim that it has been nearly overcome over the whole range of the instrument, and completely overcome within the range for which the instrument is of most practical value.

I was a little disappointed when Professor Silvanus Thompson left off at what was to me the most interesting point of his remarks, viz., when he said that he had succeeded in making the corrections in his permeameter smaller than in mine. It would have been interesting to learn by what means he accomplished this result, and I hope he will publish a working drawing of his instrument in the Proceedings. In his old permeameter he had a bar which was suspended from a spring balance and dipped down into a sort of electro-magnetic well. The contact at the bottom was made in a more or less uncertain way, and the pulling up of the sample by a spring balance must also have been a somewhat haphazard way of measuring.

Professor THOMPSON: Horizontally.

Mr. KAPP: That is a new development. But the difficulty is this: The sample must make fairly good contact where it goes through the top yoke. If the sample at that spot is not centrally guided the air resistance will vary, and the mechanical friction will also be a variable, and may be a large, quantity. The very object of reversing the process—that is, pulling away the plunger, and not the sample itself—was to be able to get the sample tight and in good contact with the top yoke, and to transfer all corrections to one piece, which is the same in every experiment.

As regards Professor Thompson's remarks on the plate-testing machine, I feel sure that on further consideration he will find that the improvement suggested by him cannot be carried out without introducing a very large source of error. The suggestion was to make the bottom yoke very large, so as to keep the induc-

tion in it under all circumstances extremely small. I started with the same idea, but had to abandon it, for various reasons. It would take me too long to give all these, but I may briefly mention the most important of them. It is, of course, essential that there should be a definite quantity of iron under test. Unless you know the quantity you are testing, you will have no means of referring the loss to unit weight. We must therefore have a definite length of sample under the influence of a definite induction. If, however, the width of the yoke is very large in comparison with the length of the sample, that part of the sample which really receives the full induction becomes an indefinite quantity, and we are thus left in doubt as to how much of the sample we are really testing. Thus you see that Professor Thompson's remedy is worse than the evil it is intended to cure. Mr. Kapp.

Professor Perry also suggested a very large yoke; and, although under his arrangement the whole of the sample would be actually under test, there would be another objection, which also applies to Professor Thompson's suggestion. This is the uncertainty as to the distribution of the density of flux within the yoke, owing to the great difference in the length of the path in various parts of the yoke.

These suggestions which occur to one at the spur of the moment may be very nice on paper, but when you come to work them out you find they are wrong.

Professor PERRY: I should like Mr. Kapp in the reprint to carefully consider that last remark of his.

Professor THOMPSON: Make the whole thing ten times as long.

Mr. KAPP: What about the cost? The sample would then have to be some 10 ft. long, and iron makers would hesitate to supply test pieces of that length.

Mr. Steele's suggestion is an excellent one, and can easily be adopted in such a testing machine as I have brought before you.

Professor Fleming has touched upon a very important matter, namely, the difference in the results obtained when the same iron is tested separately and in a transformer. I have hitherto ascribed this difference to electrical leakage, and there is no doubt that a great part of it can be so accounted for, but not all. Certain

Mr. Kapp. transformers were laid aside to be used in testing, and they would keep on getting better and better, but they never got as good as the sample of iron tested in the machine. The difference is very small, but is still perceptible. It cannot be due to Foucault currents, so far as they may be supposed to vary with the width of the plates, because it is equally present in small and large transformers. Neither is it due to the bolts which hold the plates together, for on removing the bolts the iron loss was not altered. There must be something else to account for the small difference, but what it is I cannot tell.

Mr. Sparks alluded to the variation in the quality of the iron near the edge and centre of a plate. In making up a sample the whole plate is used, and thus one gets a fair average result. As regards his question on the influence of annealing sample bars, I have tested them before and after annealing, and found that, although iron was improved by annealing, no decided improvement could be detected in steel.

Mr. Mordey has asked about the influence of time. On this point I am not able to give any information. In using the instrument I try, of course, to get the results as quickly as possible, and to get them under conditions as nearly as possible the same as when the material is used for dynamo magnets. In fact, the instrument is designed with a view to imitate to a certain extent the treatment the field magnet gets when the dynamo is at work. We have then slight vibrations of a mechanical nature, and a kind of magnetic plucking at the field lines due to the armature current. In the testing machine we have also the plucking when the plunger comes off, and the mechanical vibrations on its being arrested by the stop.

It is interesting to find that Mr. Mordey's condition which he imposes on iron-makers tallies so well with my average curve. In it we have for the induction of 2,500 about 0·35 watt per pound of iron, whilst Mr. Mordey's figure is 0·38. We have been working entirely independently, and have, nevertheless, arrived at very much the same result.

Mr. Ravenshaw alluded to the iron loss in armatures. Owing to the greater thickness of armature plates, eddy-currents are

of relatively greater importance; and to make tests on the iron intended for armature plates, it would be necessary to work the instrument at about the frequency corresponding to that of a dynamo. It is, of course, also possible to separate hysteresis and Foucault losses by testing the same sample at two different frequencies. Mr. Kapp.

The President has referred to the difficulty of facing, and described a method of testing used by his firm. The illustration he gave of the two curves tends to make me doubt that his method is reliable. Surely a magnetisation curve (relation of H and B) depends only on the quality of the iron, but not on the dimensions of the sample tested; and if his method gives different curves according to the length of the sample, it is not a true magnetisation curve as commonly understood.

The PRESIDENT: I will now ask you to give a very hearty vote of thanks to Mr. Kapp for his very interesting paper.

The vote was carried by acclamation.

The PRESIDENT: I have to announce that the scrutineers report the following candidates to have been duly elected:—

Foreign Member:

Knud Bryn.

Members:

Benjamin Walter Deakin.
George William Lowcock.

Associates:

Henry Abrahams.
Edward Neville Bray.
Alfred Collyer.
Thomas W. Ellison.
William Eversley Hardy.
George William Hodder.
Charles Henry Blackwood Longworth.
Charles Picton Martin.
John Willoughby Meares.
John William Morris.
John Walker Parr.
Evan Parry.
Gerard S. Peck.
Frank Henry Pitcher.
H. B. Price.
Alexander Brodribb Randall.
William Seymour.
Hilliard S. Stephens.
James Roberts Sykes, jun.
Lieut. Oswald T. O. K. Webber, R.E.
Gilbert Winslow, B.A.

Students:

Henry Charles Ashton.
Charles Frederick Haswell Bayly.
Ernest E. Benham.
Leonard Harry Combe.
Kenelm Edgcumbe.
Herbert Tyndale Haws.
C. F. Hesketh.
Leonard Johnstone.
Gustave Lemmens.
G. P. Roy.
Percy S. Sheardown.
R. Valle.
Harman Wigan.
J. G. Wilson, B.A.
Thomas Parry Osborne Yale.

The meeting then adjourned.

ABSTRACTS.

J. DERY and L. WEISSENBRUCH—ELECTRIC TRAIN-LIGHTING.

(*Bulletin de la Société Belge, Vol.* 10, *No.* 6, *p.* 213.)

The authors class the different systems of train-lighting as follows:—

1. With primary batteries.
2. With secondary batteries alone.
3. With accumulators and dynamos run from the axle of a carriage.
4. With accumulators and dynamo driven by a steam engine.
5. With dynamo alone driven by a steam engine.

Primary batteries are no longer used for the purpose in question. There is no train-lighting in Europe successfully worked by the use of accumulators alone, or which has passed the experimental stage. The most common system in England is the use of accumulators in conjunction with a dynamo driven from the axle of a carriage. The Midland Railway has also tried placing the dynamo on the tender and driving it from the locomotive itself.

The practice of employing accumulators charged during motion of the train by a dynamo driven from an engine is the most common in America, although the Pennsylvania Railroad uses accumulators alone; and the Chicago, Milwaukee, and St. Paul Railway uses an installation independent of any secondary battery, which can, if necessary, dispense with steam power from the locomotive. This last system is also in use on some of the Cape State railways. The difference in the systems is no doubt due to the varying conditions of the places in which they are employed.

The illumination of the carriages in different countries is a point worthy of note.

The best colza lamps, such as are employed on the Northern railways in France, have only an intensity of 7 or 8 candles. Under the best conditions, the Pintsch gas-lamp is equivalent to only 10 candles. It has been the European practice to use at the most one 10-candle-power lamp in a first class carriage with six or eight seats. On the Midland Railway two 8-candle-power lamps are used in every compartment.

The following table gives a comparison between the different modes of lighting in America, with analogous particulars for La Compagnie des Wagons-lits in France. The American figures are obtained from Mr. George Gibbs, of the Milwaukee and St. Paul Railway.

ILLUMINATION OF A PASSENGER CARRIAGE 45 FEET LONG.

—	Number of Lamps. In Main Portion.	Number of Lamps. In Lavatory.	Number of Candles. In Main Portion. Per Lamp.	Number of Candles. In Main Portion. Total.	Number of Candles. In Whole Carriage.	—
1. Candles	4	1	1	4	5	In the United States.
2. Colza Oil	12	1	12	144	156	
3. Petroleum (Moehring lamp)	12	1	12	144	156	
4. „ (Duplex lamp)	12	1	10·5	126	136·5	
5. „ (Acme lamp) ..	6	1	26	156	168	
6. Pilgas (Pintsch)	16	1	10	160	170	
7. Carburetted air (Frost) ...	4	1	42	168	180	
8. Electricity	9	1	16	144	160	
9. „	20	1	6	120	126	In Europe (Wagons-lits).

M. KRIEG—METHOD OF OBTAINING TUNGSTEN BY ELECTRICITY.

(*La Lumière Electrique, Vol.* 51, *No.* 4, *p.* 177.)

The process consists in pulverising the tungsten ore and mixing it with carbon and tar to form a paste. When placed in an arc with hollow carbons through which passes chlorine, the paste will yield chlorate of tungsten, from which tungstic acid can be made. This mixed with carbon will yield tungsten in the arc, if the operation be carried on in an atmosphere of inert gas.

C. FÉRY—PHOTOMETRY OF PROJECTORS, LIGHTHOUSES, AND OPTICAL TELEGRAPHS.

(*La Lumière Electrique, Vol.* 50, *No.* 51, *p.* 551.)

After tests made on projectors at Chicago which yielded very high figures for the illumination in the axis of the instruments, a polemic was started to determine if the above measurements were physically correct, and if the ordinary photometric laws hold in such a case.

The fundamental formula, due to Lambert, on which all such determinations depend, has apparently been neglected in the above discussion—

$$dq = E \frac{ds\, ds_1}{D^2} \cos \alpha \cos \alpha',$$

where dq is the quantity of light received by a surface, ds, placed at a distance D from an illuminating surface, ds_1, of brilliancy E.

If the surfaces ds and ds_1 be normal to the line connecting their centres, the law then becomes $e = \frac{I}{D^2}$, where I is the luminous intensity. The formula is only correct when the dimensions of the luminous source are small as compared to D. With a photometer for reducing to equal illumination the two sources to be compared, $\frac{I}{D^2} = \frac{I_1}{D^2_1}$. When any optical system is introduced between the source of light and the photometer, matters become more complicated.

If the system be so arranged as to give parallel rays of light, there will exist an ambiguity as to the law of illumination. Some say that the intensity in the parallel beam is independent of distance; others maintain that the law of inverse squares must be applied, the objective being taken as the source of light. The author considers that both contentions are correct within certain limits. The source of light in practice is not a mathematical point, and consequently the rays of light from the objective will not be quite parallel.

The electric arc nearly approaches the above conditions. Each ray of light will be transformed into a small cone from the lens, with an angle $a = \frac{d}{f}$; d being the diameter of crater, and f the focal length of the lens.

A photometric screen of small surface placed very close to the objective will receive rays only from a certain number of points on the lens surface. This active surface will be proportional to the distance of the screen from the lens, and up to a certain distance, x, from the lens the amount of light received by the photometer will be a constant; the ratio of the surface to the square of the distance being also a constant, $x = \frac{Df}{d}$, where D is the diameter of the lens. If the photometer be moved away further than the point x, the illumination varies according to the ordinary law, viz., inversely as the square of the distance.

Advocates of the first opinion are correct for distances up to the point x (which becomes infinitely distant when the source of illumination becomes infinitely small). Their adversaries, on the contrary, are correct beyond the point x.

Under working conditions the distance between the projector and the point x may be considerable. In the case of a lens 1 metre diameter and 1·5 metres focus, illuminated by a crater of 5 mm. diameter, $x = 300$ metres. At this point the lens appears uniformly illuminated, and may be considered as a true source of light when viewed along its optical axis.

In this case the multiplying power of the system would be 90,000—the number by which the illumination at a given distance due to the naked arc would be multiplied, to give at the same distance the illumination due to the projector.

It would, however, be a mistake to use this multiplier, as was done at Chicago, to obtain the illumination at a distance of 1 metre, which gave a result of 270,000,000 candles with the projector—an intensity not to be obtained at any point in the axis. If the photometer were placed quite close to the lens, an illumination of 1,333 candles should be obtained with the above conditions, which

will be constant up to a distance of 300 metres from the projector; and the author considers that it is only by a direct photometric measurement of the sort that practical results are to be obtained.

The author carried out a series of experiments on a non-achromatic lens of 14 mm. diameter and of 45 cm. focal length, the source of light being a circular diaphragm 1·4 cm. diameter, illuminated by a Bengel jet, thus obtaining a luminous surface of fixed dimensions and of uniform brilliancy.

The results showed a gradual decrease in light up to the point x, and beyond that the decrease followed the law of inverse squares, taking the lens as the origin.

The above results are due to the great difficulty in obtaining correctly the focus of non-achromatic lenses; the distance between the extreme coloured foci being about 40 times greater than the spherical aberration.

The author then made experiments with a lens sensibly deprived of the two aberrations for parallel rays in the direction of the axis. The lens was an astronomical objective with the following constants:—D = 7 cm.; f = 78 cm. The following table gives the results of the tests. The constant difference between experimental and calculated values is attributed to reflection from the four faces of the two lenses constituting the achromatic objective. All the preceding remarks apply equally to projectors fitted with mirrors.

Distance of Photometer from Source of Light.	$\frac{1}{D^2}$ Observed.	$\frac{1}{D^2}$ Calculated.
78 cm.	3·30	3·70
128 „	3·19	3·70
178 „	3·30	3·70
278 „	3·25	3·70
378 „	3·19	3·70
428 „	3·30	3·70
528 „	1·88	2·76
578 „	1·56	2·24
678 „	1·18	1·57
778 „	0·735	1·15
1,078 „	0·255	0·56
1,578 „	0·111	0·24

The concordance between these results shows that the differences observed in practice are either due to the wrong application of formulæ or to personal errors in the observers.

P. BOUCHEROT—THEORY OF ROTARY FIELD MACHINES.

(La Lumière Electrique, Vol. 50, No. 44, p. 220, No. 50, p. 524.)

The author shows that it is solely the self-induction of the armature which causes maximum torque at a high speed—a practical inconvenience with

such machines. An alternative, but uneconomical, method is to work the motors below their full load. The two main disadvantages of machines with rotating magnetic fields are that one must either work uneconomically or be subject to sudden stoppages. Many expedients have been tried, without much success.

The grouping of the armature winding has been considered, from which emanated the squirrel-cage winding. This was not very successful, for, although the relation $\eta^2 \gtrless L\, \Lambda$ is required by existing conditions—where η is the maximum coefficient of mutual induction, L the coefficient of self-induction of the magnets, and Λ the coefficient of self-induction of the armature—it also becomes a serious obstacle. The value L being fixed, all that is done to diminish Λ will also diminish η, and the best condition is arrived at when $\eta^2 = L\, \Lambda$, assuming no leakage. A second expedient has been the use of condensers; there is, however, not much to be expected from their use, on account of the great variations of frequency of the armature current. A condenser which would cause maximum torque at starting would also make the torque very small at high speeds. Suppose, for instance, that the condenser introduced in the armature circuit completely annuls self-induction at starting, and produces a torque of 5 m.k., the speed of the field being 1,200 revolutions per minute. At 1,000 revolutions per minute the inductance due to self-induction will be six times smaller; the inductance of the condenser, on the contrary, will be six times greater. The resultant inductance will then be 5·83 times greater than that due to self-induction or to the condenser on starting.

The inductance due to self-induction on starting, is six times greater than the resistance (since the condition $r = w\, l$ corresponds to a difference in speed of 200 revolutions between the armature and the field). The total inductance at 1,000 revolutions will be 35 times greater than the resistance, and the torque will be a minimum. It then becomes detrimental to normal working conditions to obtain maximum torque on starting.

The last expedient is to introduce resistances into the armature circuit which must be varied with the speed, so that the resistance would always be maintained equal to the inductance of the armature. The author does not consider this practical.

A commercial motor should have at any speed an increased torque with diminution of speed, and *vice versâ*. The torque would then have to be a maximum at starting. There is not a motor on the market with rotating fields, to satisfy these conditions. To approach these conditions it is necessary to work under full load at a sacrifice of efficiency.

In the case mentioned above, the motor would work well with 200 revolutions per minute of the field, but the output would be small. This is why such motors are worked at low frequencies.

The author considers that it is for this reason that many makers have placed the armature outside and field magnets inside, apart from the reason of diminishing losses due to hysteresis and Foucault currents.

With regard to efficiency, the author states that the efficiency of the armature is equal to the ratio of its speed to that of the field. The efficiency then increases indefinitely with the speed. Considering the whole machine, the efficiency must

reach a maximum value; and there is no reason that, with careful designing, the efficiency should not be equal to that of a continuous-current machine.

In an answer to criticisms made by M. Farman, the author states the three theories of rotating fields, as follows:—

1. In the first case one finds the flux produced by two sine currents with a quarter phase difference between them, circulating round the field magnets, placed at right angles. Under these conditions the field rotates; so will also a ring placed in the field, but at a different speed. The currents produced in the ring, and their reaction on the field magnets, must be determined. This theory is employed by M. Picou and M. Mascart.

2. In the second case one considers the action of the alternating fields produced by the field windings on the armature, and the reaction of the armature on the field circuits. This is what M. Farman has attempted without success, and also MM. Boissonnas.

3. In this case one considers self and mutual induction only, the field not being taken into account. This method has been successfully employed by MM. Hutin & Leblanc.

ANON.—ELECTRICITY IN PUBLIC WORKS (CONSTRUCTION OF BILBAO HARBOUR).

(*La Lumière Electrique, Vol.* 51, *No.* 4, *p.* 177.)

Since 1878 the tonnage of the ships which have entered the port of Bilbao has increased by 520 per cent., and attained in 1891-92 a total of 4,500,000 tons.

Although the harbour was considerably improved in 1890, navigation remained difficult under certain conditions; it was therefore decided to build a harbour in the deep water of the bay.

This will be protected by two breakwaters, one 1,450 and the other 1,072 metres long. The area of the harbour will be 287 hectares. The stones required for this work are obtained from a neighbouring quarry, where they are shipped by means of steam cranes. Engines are installed at the quarry for working shop machines, a pile-driver, pump, and three cranes on the loading platform, and also a dynamo for driving motors on the travellers used for moving blocks of artificial stone.

The volume of these blocks is about 18,000 cubic metres; when dried they are moved by the electric travellers for shipment to the breakwaters.

The dynamo is compound-wound and of the multipolar type, working at 220 volts and 300 revolutions per minute, and driven direct from a 50- to 60-H.P. engine. The armature is ring-wound.

The lines for working the travellers are of bare copper, carried on insulators fixed to posts or to walls, according to circumstances.

The traveller is very simple in construction; it is supported on eight wheels 0·85 metre diameter.

The two supporting frames are 5·7 metres apart, and connected together at

the top by two strong horizontal beams. These beams carry two hydraulic lifts. A cab placed at the top contains a pump, the necessary gearing, and the motor. The latter is of the two-pole Gramme type, and drives by worm gearing. Current is collected from the overhead wires by means of the ordinary form of trolley bars. The motor works at 630 revolutions per minute, and the crank shaft of the pump works at 30.

The traveller is arranged to run on to a large platform, on which it deposits the blocks. The platform is also propelled electrically.

Some trouble was experienced on account of the sinking of the rails in places, which necessitated extra work for the motor.

Under normal conditions 12 H.P. is necessary for moving a block weighing 100 tons, but 40 H.P. was required in places where the ground had sunk. This load, however, was only momentary. The travelling platform measures 6 metres × 4·6 metres, and has 4 axles, to which are fixed wheels 0·6 metre diameter, running on two pairs of rails. The motor working this platform is similar in every respect to that working the traveller, the reduction in speed in this case being 105 : 1. This platform is used for shifting the blocks to the wharf for shipment.

ANON.—THE DOANE LIGHTNING ARRESTER.

(*La Lumière Electrique, Vol.* 51, *No.* 2, *p.* 72.)

This lightning arrester has been specially designed for tramway work. A branch circuit is made from the trolley to one of two carbon rods, the other one being connected to earth. When the potential rises to a given amount, an arc is established between two carbon points, current passing to earth. A part of this current excites a solenoid which attracts an armature and causes a mica screen to be interposed between the two carbons, thus interrupting the arc. The armature is then released, and the instrument will again be ready for action.

M. A. BANTI—EXPERIMENTS ON NON-SYNCHRONOUS SINGLE-PHASE MOTORS.

(*La Lumière Electrique, Vol.* 51, *No.* 2, *p.* 72.)

These experiments were made on some Brown-Boveri motors in use at the National Bank of Rome.

The author recalls the principle on which are based non-synchronous single-phase motors. The torque is zero at starting and at the speed corresponding to synchronism, and is maximum at an intermediate speed. The motors tested had outputs of $\frac{3}{4}$, $1\frac{1}{2}$, and 3 H.P. The field has two windings in order to produce a rotary field; the difference in phase between the two currents being about 90°. This is obtained by putting the two circuits in parallel and inserting in one of

the circuits a polarising battery which acts as a condenser. The 3-H.P. motor, which was first tested, has the following dimensions:—42 cm. long, 44 cm. wide, and 43·5 cm. high.

The field magnet carries 12 coils, six belonging to the ordinary field circuit, and the six others to the starting circuit. The armature has 38 copper bars.

Weight of motor, including pulley, is 190 kilogrammes. The motor was started in the ordinary manner. When synchronism was attained, the second field winding was cut out and the motor loaded by means of a brake. The watts supplied were measured by a Ganz wattmeter; note being also made of exciting current and supply voltage.

The results obtained are given in the following table:—

3-H.P. MOTOR.

Watts Absorbed.	Amperes.	Speed.	Available Horse-Power.	Efficiency.	Power-Factor, $\frac{W}{AV}$.	Ratio of Apparent Energy to Real Energy, $100\frac{V\times A-W}{W}$.
				%		
343·0	15·0	902	—	—	0·215	364·86
967·7	17·5	890	0·82	62	0·521	92·23
1,421·0	21·0	870	1·38	71	0·637	57·09
1,911·0	24·0	884	2·01	77	0·751	33·44
2,401·0	27·5	872	2·54	78	0·819	21·75
2,976·7	32·3	872	3·16	78	0·869	13·54
3,503·5	37·0	860	3·67	77	0·892	12·26
4,189·5	43·0	868	4·19	73	0·917	9·10
4,806·9	48·5	848	4·60	71	0·934	7·25
5,439·9	55·0	860	5·07	68	0·934	7·49

Curves are given connecting—

Supply watts with brake horse-power.
Apparent watts ,, ,, ,,
Efficiency ,, ,, ,,
Power-factor ,, ,, ,,

The efficiency is maximum for an available output of about 3 H.P., and is 78 per cent. The angle of lag was found to be 20°. The motor was loaded up to 5 H.P. without varying speed by more than 5 per cent. from 0 load. These results apparently contradict statements made against single-phase non-synchronous motors, for in this particular case the motor withstood a considerably greater effort than that for which it was designed, without an unsafe variation in speed. At starting, when the two field circuits are excited, the current is 55 amperes, and gradually decreases to 42 amperes when synchronism is reached.

For a 2- or 3-H.P. motor a 6-kilowatt transformer is necessary.

The same motor was tested with an armature smaller in diameter than the first, thus offering a larger air gap. The results are given in the following table:—

3-H.P. Motor.

Watts Absorbed.	Amperes.	Speed.	Available Horse Power.	Efficiency.	Power-Factor, $\frac{W}{AV}$.	Ratio of Apparent Energy to Real Energy, $100\frac{V \times A - W}{W}$.
				%		
379·75	18·0	916	—	—	0·197	405·0
862·4	20·0	896	0·70	60	0·400	147·2
1,384·2	22·5	892	1·36	72	0·577	73·3
1,901·2	26·2	864	1·9	74	0·680	49·9
2,437·7	30·0	908	2·58	78	0·762	31·1
2,940·0	34·5	872	3·1	78	0·799	25·1
3,552·5	39·5	888	3·7	77	0·843	18·5
4,324·2	47·0	876	4·19	71	0·868	15 9
4,961·2	53·0	856	4·68	69	0·878	13·9

The 1½-H.P. motor was next tested. It had the following dimensions:—36 cm. long, 38 cm. wide, 37·5 cm. high. There were eight field coils. The armature had 37 copper bars. Total weight of machine, 120 kilogrammes.

The following are the results obtained :—

1½-H.P. Motor.

Watts Absorbed.	Amperes.	Speed.	Available Horse-Power.	Efficiency.	Power-Factor, $\frac{W}{AV}$.	Ratio of Apparent Energy to Real Energy, $100\frac{V \times A - W}{W}$.
				%		
220·5	7·0	1,336	—	—	0·294	239·7
931·0	11·0	1,352	0·97	76	0·793	26·4
1,249·5	14·0	1,332	1·27	74	0·833	19·9
1,372·0	15·0	1,356	1·37	73	0·854	17·0
1,641·5	17·5	1.360	1·64	73	0·877	10·8
1,874·0	20·0	1,308	1·83	72	0·875	14·2
2,205·0	22·5	1,300	2·11	70	0 917	9·18
2,756·2	27·5	1,264	2·26	60	0·930	6·75

The maximum efficiency of 73 per cent. corresponds to a load of 1·6 H.P.—a little above the normal value. The difference of phase was 28°.

The speed remained almost constant when the motor was loaded to twice full load.

The smallest motor was next tested. It measured 31 cm. long, 31 cm. wide, and 31·5 cm. high. It had eight field coils. The armature had 35 bars of copper. The whole machine weighed about 70 kilogrammes.

The following table gives the results obtained on this motor:—

$\frac{3}{4}$-H.P. MOTOR.

Watts Absorbed.	Amperes.	Speed.	Available Horse-Power.	Efficiency.	Power-Factor, $\frac{W}{AV}$.	Ratio of Apparent Energy to Real Energy, $100 \frac{V \times A - W}{W}$.
				%		
122·5	4·0	1,372	—	—	0·286	249·4
347·9	5·0	1,360	0·31	65	0·649	53·8
465·5	6·0	1,376	0·45	71	0·725	37·9
617·4	7·3	1,312	0·59	71	0·795	26·5
845·2	9·5	1,332	0·84	73	0·833	20·3

The efficiency under normal conditions is ·71 per cent. for the above motor.

The starting apparatus mentioned above, consisting of resistance, commutator, condenser, &c., is used for starting all the motors in the installation

G. CLAUDE—CONTRIBUTION TO THE STUDY OF THE ALTERNATE-CURRENT ARC.

(*Comptes Rendus, Vol.* 118, *No.* 4, *p.* 187.)

A condenser of 0·1 microfarad capacity was placed in series with a short-circuiting key and 12 incandescent lamps of 16 C.P. on an alternating P.D. of 2,400 volts at 80 ∿. On closing the circuit the lamps glowed with the charge and discharge current of the condenser, which was about 0·1 ampere. When the key was lifted in order to introduce a small gap, a permanent arc was established between the two points, and it was observed at the same time that the brilliancy of the lamps increased considerably as the arc got longer. When the gap was increased to 1 mm.—just sufficient to keep a stable arc—the potential difference at the terminals of each of the lamps, measured with an electrometer, was increased from 30 to 90 volts.

The addition of the arc in series with the lamps then had the effect of increasing the current in the ratio of 1 : 4, taking into account the variation in the resistance of the lamps.

The potential difference at the terminals of the arc, measured with an electrometer, was 1,200 volts. The current was about 0·4 ampere. If this arc acted as an ordinary resistance the power absorbed would be 480 watts. This was not, however, the case, for the key kept cool after several minutes' action.

It would, then, seem that the arc acted as a self-induction, and, when placed in series with a capacity, considerably diminished the apparent resistance of the circuit. The author, however, gives a different explanation. When the distance between the points of the key is greater than the sparking distance corresponding to the E.M.F. in question, the arc would no longer be maintained, and con-

sequently the condenser would not be charged. When the E.M.F. has attained the necessary value the arc will be re-established.

The difference of potential at the terminals of the key falls to zero, and the condenser is rapidly charged with a large E.M.F. The charging current is limited to a small fraction of the period, and is therefore greater.

The mean of the squares of the current is much increased, and consequently the power absorbed by the lamps is greater. An analogous action takes place at the time of discharge. The explanation of the small amount of power absorbed by the arc is now evident; for when the difference of potential at the terminals of the lamps is great the current is zero; but the mean of the squares of the P.D., measured on the electrometer, is not diminished. The phenomenon is considerably influenced by the length of arc and nature of the electrodes. With carbon points it is scarcely possible to obtain more than 500 to 600 volts across an arc 3 to 4 mm. long.

The figures given above are the most favourable ones obtained with the particular P.D. and frequency employed.

It is not possible to follow the steps of the operation *de visu* with a frequency of 80; but it is an easy matter to do so when using a current of 3 or 4 periods per second at 170 volts obtained from a Gramme machine. When working with a condenser of 1 microfarad capacity and a 0·3 ampere lamp, the author observed well-marked intervals of brightness and dulness; whereas the filament kept quite bright when the short-circuit key was closed.

C. NOURRISSON—ON THE MINIMUM ELECTRO-MOTIVE FORCE NECESSARY TO PRODUCE ELECTROLYSIS OF DISSOLVED ALKALINE SALTS.

(*Comptes Rendus*, *Vol.* 118, *No.* 4, *p.* 189.)

The author has endeavoured to calculate, from thermo-chemical laws, the minimum necessary electro-motive force to produce electrolysis of dissolved alkaline salts, the initial and final condition of the solution only being considered. These calculations were also verified by experimental data.

Taking, for example, chloride of sodium, and assuming that there is complete decomposition, the following four reactions may be said to represent electrolysis:—

	Cal.
1. Na Cl = Na + Cl in solution, with absorption of ...	96·4
2. $H^2O = H^2 + O$ „ „ ...	68·4
	164·8
3. Na + O + H + Aq = a O H, producing	111·8
4. Formation of oxygen compound of Cl...	6·0
	117·8

The difference is 164·8 − 117·8 = 47 calories, and the electric current would

have to supply energy equal to this to electrolyse one equivalent of chloride of sodium. The electro-motive force would then be 2·02 volts.

By calculation—

	Cal.		Volts.
For Na Br	40·6	...	1·75
For Na I	26·9	...	1·16

Results which have been confirmed experimentally.

In the case of sulphate of sodium—

	Cal.
1. $So^4 Na^2 = S + O^4 + Na^2$, with absorption of	329
2. $2 H^2 O = 2 H^2 + O^2$, with absorption of	136·8
	465·8
3. $S + O^3 + Aq = S O^4 H^2$, producing	142 5
4. $Na^2 + O^2 + H^2 + Aq = 2 Na O H$ in solution, producing...	223·6
	366·1

Difference ... ... 99·7 cal.

The minimum electro-motive force works out to 2·15 volts, as sulphuric acid is dibasic. Nitrate and chlorate of sodium both require ; 48 calories, or 2·07 volts. The minimum electro-motive force necessary to produce electrolysis of dissolved alkaline salts is constant for oxygen salts, and also for haloid salts derived from the same acid.

The following table gives the results of the author's experiments :—

——	Chlorides.	Bromides.	Iodides.	Sulphates.	Nitrates.	Chlorates.
Potassium	1·97	1·74	1·15	2·40	2·32	2·45
Sodium	2·10	1·71	1·19	2·40	2·36	2·42
Lithium	2·01	1·71	1 19	2·43	2·45	2·42
Calcium	1·95	1·71	1·16	2·48	2·28	2·42
Barium	1·94	1·72	1·17	2·43	2·37	2·48
Ammonium	1·83	1·46	1·17	2·29	2·37	2·48
Calculated values ...	2·02	1·75	1·16	2·15	2·07	2·07

H. NAGAOKA—HYSTERESIS ATTENDING THE CHANGE OF LENGTH BY MAGNETISATION IN NICKEL AND IRON.

(*Philosophical Magazine, Vol.* 37, *No.* 224, *p.* 131.)

An account of a delicate and elaborate research. The result for nickel is described as follows :—The wire was 19·4 cm. long, and 2·04 mm. thick, and was carefully annealed while lying due magnetic east and west. It was then placed in a magnetic field, which was gradually raised to 10·2 C.G.S. units. The wire contracted, at first slowly, but with an increasing rapidity when the field was about 8. As the field was diminished the wire tended to return to its former state, but not by the same course, showing distinct hysteresis. When the current was cut off the wire

remained contracted $38 \cdot 2 \times 10^{-8}$ of its original length. When the current was reversed the wire continued expanding till the field reached 5, when it began again to contract, the length in a field of $-10 \cdot 1$ being nearly the same as in one of $+10 \cdot 2$. On the current being now decreased the same succession of changes took place. Similar results were obtained with maximum fields of 30 and 250 C.G.S. units. The curves have two points of inflection, one in weak and one in strong fields, but no maximum contraction was observed.

For iron, the phenomena are extremely curious and interesting. The effect of increasing the field is a gradually increasing elongation: the rate of increase reaches a maximum, and a maximum elongation is observed in a field of 70; in stronger fields the elongation steadily decreases, up to a field of 305, the largest used; as the field decreases, the wire again elongates, but shows lagging until a field of 120 is reached, when it crosses the ascending curve, and the elongation becomes greater in the falling than in the rising curve until a field of 25 is reached, when the wire again begins to shorten abruptly; on crossing zero line the wire is still longer than at the first maximum. With reversed field the wire decreases in length till -15 is reached, when it again begins to elongate, and goes on lengthening till it reaches again a maximum at -70, after which it rapidly contracts down to a field of -300. The cycle is repeated with decreasing negative field. The measured changes of length for both nickel and iron (maximum) agree with those of Bidwell. The apparatus used is fully described, and interesting curves (accompanied by the actual observations) are given.

Professor C. G. KNOTT—MAGNETIC ELONGATION AND MAGNETIC-TWIST CYCLES.

(*Philosophical Magazine, Vol.* 37, *No.* 224, *p.* 141.)

The author considers that Mr. Nagaoka (see last abstract) has done for the magnetic-elongation cycle what Warburg and Ewing did for the magnetisation cycle, and describes some closely related results obtained some years ago by himself. Wiedemann discovered in 1858 that when a longitudinally magnetised iron wire has a current flowing in it, it twists; and in 1883 the author found that nickel did the same; and more recently still cobalt was found to act similarly. Maxwell suggested that this phenomenon could be explained by the elongation discovered by Joule, and the behaviour of nickel and cobalt has confirmed his hypothesis. With a constant current flowing in the wire, the field in which it lay was altered, and a cycle of twist plotted against field was obtained which shows distinct hysteresis. With a small range of field the curve was very similar to the well-known hysteresis curve of magnetisation, but with limiting fields stronger than that which produced the maximum twist the hysteresis curve crossed itself twice and formed three loops. It is curious to note that if the curve obtained with negative field be plotted also as a positive field, taking its reflection on the opposite side of the vertical axis, and the two curves have the corners rounded off at the points of intersection, the result is a curve precisely similar to Mr. Nagaoka's. Although there is no maximum contraction for nickel, its magnetic-twist cycle is similar to that of iron, the field being higher. The field of maximum twist depends on the

current in the wire. The results of Mr. Nagaoka's experiments agree perfectly with what might be inferred from the character of the hysteresis in the magnetic-twist cycle.

F. UPPENBORN—THE CENTRAL STATIONS OF MESSRS. SIEMENS & HALSKE: III.—COPENHAGEN.

(*Elektrotechnische Zeitschrift, No.* 1, 1894, *p.* 2.)

The contract was concluded on October 30th, 1890, but, owing to the delays in building caused by the severe winter, the laying of the cables and the putting down of the boilers were only begun early in June, and it was October before the engine and accumulator rooms were ready for the plant; while the supply was begun on March 5th, 1892, since when it has continued without interruption. The system is three-wire, at 2 × 110 volts. There are six water-tube boilers of Steinmüller and Babcock & Wilcox manufacture, and there is room for five more when required; these boilers being fed by Worthington pumps. The steam supply pipes are of copper and wrought iron, and can be cut off from both engines and boilers. In the engine room there have been put down for present supply one engine of 330 H.P., and two of 550 H.P. each, and there is room allowed for two steam dynamos of 1,000 H.P. The engines, by Burmaister & Wains, of Copenhagen, are slow-speed compound condensing machines, running at about 120 revolutions per minute, and are started by small auxiliary engines, which are automatically cut off when the big machines begin to receive steam. The guarantee for the steam consumption of the larger machines was 13·2 lbs. of steam per I.H.P.-hour, the efficiency 87 per cent. The engines are coupled each to two inside-pole machines of the well-known Siemens & Halske type, which is the only one found by this firm to be practicable for very large outputs

The accumulators are of the Tudor type, so extensively employed on the Continent, having a maximum discharge current of about 350 amperes. The switch-board is of cast iron and marble, all combustible material having been avoided, and contains all the instruments, which are arranged much as usual. A differential voltmeter is provided for each dynamo, in order to couple it to the omnibus bars when its difference of potential is exactly equal to theirs. The cable network consists chiefly of double iron-armoured conductors, laid directly in the earth, a few points only being provided with bare conductors in conduits, and is arranged to have a maximum drop from the omnibus bars to the main feeding points of 15 per cent. The cables are about 100,000 yards in length, exclusive of public lighting and house services; and the insulation measured over 7,000 megohms per mile. The maximum output of the dynamo is 1,430 H.P., and of the cells about 250 H.P., corresponding to about 30,000 30-watt lamps; the cable network being designed for about 40,000 lamps burning simultaneously. There are at present about 30,000 lamps on the mains. The buildings have some pretensions to architectural beauty, the engine room especially being said to be both imposing and pleasing, good use being made of tile decoration.

C. P. STEINMETZ—POLYPHASE MOTORS.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 4, *p.* 45.)

After going into the history of these motors, which he traces back to a paper read by Mr. Walter Baily to the Physical Society of London in 1879, the author makes some remarks on the characteristics of this kind of motor as they have shown themselves in his experience.

Firstly, polyphase motors are more easily dealt with by calculation than, for example, direct-current motors—especially as regards starting torque, efficiency, displacement of phase, alteration of speed for given load, maximum overload possible, and torque under these conditions; also current taken when running light or at different loads, and so forth.

Starting Torque.—The ordinary polyphase motor can produce the same torque per watt at starting (sometimes a few per cent. more) as at full speed and load, and requires no excessive current to start it. By special design, the starting torque may be made as much as three times the full speed and load torque for the same current. All motors of 5 H.P. full-load output which take 15 H.P. to start them must be regarded as failures.

Overloading.—A polyphase motor can be considerably overloaded without stopping or dropping in the speed to a serious extent: the conditions of use determine the amount of overloading for which the motor must be designed.

Fall of Speed.—This can be made as great or as small as is desired, without perceptibly affecting the other qualities of the motor. Generally speaking, the fall is less than with direct-current motors.

Efficiency.—The efficiency should be at least as great as with direct currents; but, as in the latter case, the higher the efficiency the greater the cost of manufacture, and *vice versâ.*

Current at no Load.—The current taken at no load must be small, and should not amount to more than 20 to 30 per cent. of the full-load current, except in special cases—as, for instance, if the motor is required to stand overloading several hundred per cent. for short times, without a great fall in speed. This point is one in which faulty design is very plainly indicated.

Phase Displacement.—The displacement of the current behind the E.M.F. should be small, and the energy-factor, or ratio of true to apparent watts, large. It should be about 0·9 in large motors, and never under 0·8. It consists of three important components—

(*a.*) The self-induction of the armature, displacing the armature current behind the inducing E.M.F. This increases more and more rapidly with increasing output, and is the chief factor in limiting the load.

(*b.*) The self-induction of the primary circuit, causing the main current to lag behind the terminal P.D. This also increases with the load.

(*c.*) The magnetising or exciting current, increasing this last effect. As this current is constant, the phase displacement produced by it diminishes with increased output, almost proportionally. The resultant phase displacement decreases from no load, reaches a minimum, and then increases with increasing load.

Frequency.—Generally speaking, any frequency from 130 $\sim$ downwards may be chosen, varying the speed accordingly. But with high frequencies the no-load current becomes great, and the phase displacement is increased.

The author sums up by saying that polyphase motors have only one advantage over single-phase, and that is, their greater starting torque; and in cases where this is of no use ordinary alternate currents should be used. It is a mistake to always use induction motors with alternating currents; the synchronous form should always be used where possible, the latter having the advantage of no phase displacement, thus making the no-load current negligible, and the load current proportional to the output, as in the direct-current form. A polyphase synchronous motor starts itself on light loads. It was, therefore, a mistake to use a non-synchronous motor in the historic Lauffen-Frankfort power transmission.

Dr. BEHN-ESCHENBURG—INCREASING THE NUMBER OF EXCITING PHASES FOR THE PRODUCTION OF ROTARY MAGNETIC FIELDS.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 3, *p.* 35.)

If a magnet be surrounded by two coils through which alternating currents of different phase are passed, each having the same effective magnetising force, the magnetisation of the iron takes a phase intermediate between those of the exciting currents. If two equal currents differing 90° in phase be passed through coils having w_1 turns, the magneto-motive force is proportional to

$$w_1 \, A (\sin p\, t + \cos p\, t) = \sqrt{2}\, w_1 \, A \sin \left(p\, t + \frac{\pi}{4}\right).$$

By the same means it is possible with an unsymmetrical arrangement of the given phases—for instance, in a two-phase system with 60° phase displacement—to obtain a symmetrical distribution of field. In the instance given, by suitable combinations, fields may be obtained in six phases regularly distributed at intervals of 60°. A generalised formula is given for increasing to any extent the number of phases from two upwards.

A. RAPS—REGISTERING VOLTMETER.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 1, *p.* 15.)

This voltmeter is of the photographic recording type, and is remarkable for its simplicity of construction. It consists essentially of a light-tight box, in which a drum rotates on which the sensitive paper is stretched. The box has a slit on one side, the paper passing close behind it. Immediately in front of the slit passes the hand of the indicating voltmeter, and in front of this again is a lamp, which throws an image of the slit on the sensitive paper. As this rotates, the shadow of the hand of the indicating voltmeter produces a white line on a dark background (after development). There is no printing on the paper. The lines indicating volts are produced photographically by the shadows of wires stretched across the slit in the required position; while a glass disc rotates, by the action of

gearing from the drum, in front of the slit, and, being marked with radial lines and figures, throws shadows on the paper when these cross the slit. There is therefore no adjustment of tension required, and no unequal expansion of the paper affects the accuracy of the record. Any suitable indicating voltmeter can be used, the scale being marked by the cross wires in a suitable manner.

There are arrangements provided for introducing fresh paper without risk of exposure to light, and development and fixation also may be conducted in full daylight; no skill being required for the latter operations, as the record need only be subjected to the action of the developer for a given time, the exposure being perfectly regular. The Allgemeine Elektricitäts Gesellschaft are the manufacturers of this voltmeter.

Professor G. M. MINCHIN—THE ACTION OF ELECTRO-MAGNETIC RADIATIONS ON FILMS CONTAINING METALLIC POWDERS.

(*Philosophical Magazine, Vol.* 37, *No.* 224, *p.* 90.)

Monsieur E. Branly discovered that a glass tube filled with copper filings so closely as to form an apparently continuous column of metal is in a sensitive state as regards conductivity, and can be made either a conductor or a non-conductor by tapping the tube.

Mr. Croft, at the Physical Society, showed that, when the tube is a non-conductor, if a spark be passed anywhere in the neighbourhood between the knobs of a Leyden jar or the poles of an induction coil, the electro-magnetic radiations render the column a conductor. This experiment struck the author as having a resemblance to the effects of radiation on photo-electric impulsion cells (*Philosophical Magazine*, March, 1891), in which case it was found that, generally speaking, the length of the electro-magnetic waves has an influence on the phenomena, only certain wave-lengths being competent to produce the effects. In reproducing Monsieur Branly's experiments, the author finds that the powders should not be too coarse nor too fine to produce the best results.

The author has also experimented in the following manner:—He takes a glass plate on which he forms, by means of gelatine or collodion shaken up with metallic powder, a film, the layer next the plate being the metallic film used. Now, if the film be clamped in one place by a suitable metallic clip, forming one terminal of the circuit, and touched at another point by the other terminal, it is found that no conduction takes place, even when an induction coil is sparking a few feet from the film. But if the circuit be touched at any point on the wires leading to the film with an electrified body, the insulation breaks down and a current passes; and gradually the distance between the terminals can be increased, touching the circuit with an electrified body at each step, until the whole film becomes conducting. A curious point is that if, when the film is conducting, the circuit be broken by removing the terminal knob from the film, the latter becomes a non-conductor; but if circuit be broken at any other point, the film remains a conductor for (apparently) any length of time. Breaking circuit at the film instantly destroys its conductivity, unless it is an old one, in which case an appreciable time, say half a minute, must elapse before remaking the circuit in order

to effect a destruction of the conductivity. The author considers this due to the hindrance caused to the movement of the particles by the hardening of the gelatine or collodion film.

These films are less sensitive to mechanical disturbances than the tubes of filings. Heat does not appear to affect them; but the conductivity can be destroyed by moisture, being always restored by electro-magnetic radiations. The more rapid vibrations of light do not seem to affect the films.

The author considers the prime cause of the action to be the electrical surgings in the wires touched by the electrified body or affected by the radiation; but the state of the film at the points of contact affects the results very much. These phenomena are closely allied to those of impulsion cells.

Professor OLIVER LODGE—ON THE SUDDEN ACQUISITION OF CONDUCTING POWER BY A SERIES OF DISCRETE METALLIC PARTICLES.

(*Philosophical Magazine*, *Vol.* 37, *No.* 224, *p.* 94.)

The author is reminded by Mr. Croft and Professor Minchin's experiments of an observation made by himself when engaged on the syntonic arrangement of Leyden jar circuits. He found that, if the knobs of the receiver were very close together, a weak battery and bell being in circuit, the occurrence of a spark at the receiver knobs set the bell ringing for some time, and showing feeble contact between the knobs. The effect was as if the skin had been broken so as to cause adhesion to set in at more than the usual distance. Analogous are Lord Rayleigh's observations that electrified sealing wax near a vertical water jet caused coherence of drops that would otherwise have rebounded, and that a difference of potential of one or two volts caused a pair of impinging jets to cease to rebound. The adhesion of dust particles in electrified air is a more violent variety of the same kind of effect. The author explains Lord Rayleigh's experiments electrolytically as due to the polarisation of the water drops, or the formation in each drop of molecular chains, each with a negatively charged oxygen atom at one end and a positively charged hydrogen atom at the other. Such drops colliding about their poles would be attracted not only by the ordinary cohesive forces, but also by electrostatic forces, and thus cohesion might be set up over a greater than usual range. The author suggests that the conductivity of a chain of filings under polarising influence may be due to a similar cause, and the interruption by a tap is easily explicable. Not so the restoration of conductivity by a tap, if this be a fact.

U. BEHN—ON THE STRIATED ARRANGEMENT OF GALVANIC DEPOSITS.

(*Wiedemann's Annalen*, *Vol.* 51, *No.* 1, *p.* 105.)

The article is one of some interest, and is well illustrated by numerous photographs showing the striated arrangement of deposits of various metals as produced

under the conditions described. The author comes to the following conclusions:— The striated arrangement of galvanic deposits has for cause the alterations in strength of solution which produce currents of the liquid during the electrolysis. In the case of silver nitrate the striations are best produced with a strong solution and weak current-density. A high temperature appears also to be favourable to their formation. The E.M.F. applied has no influence on the character of the results. The same effects are produced by electrolysis of copper sulphate, the chief point here being also a low current-density; but the strength of solution does not affect the results to the same extent. The same phenomena are observed in the case of acetate of lead and sulphate of zinc, but with diminished intensity. Nickel salts appear always to give smooth deposits.

CLASSIFIED LIST OF ARTICLES

RELATING TO

ELECTRICITY AND MAGNETISM

Appearing in some of the principal Technical Journals during the month of JANUARY, 1894.

S. denotes a series of articles. I. denotes fully illustrated.

LIGHTING AND POWER.

G. CLAUDE—Contribution to the Study of the Alternate-Current Arc.—*C. R.*, vol. 118, No. 4, p. 187.

J. BOURQUIN—The Employment of Gas Engines in Private and Public Electric Light Stations.—*Lum. El.*, vol. 51, No. 2, p. 51, No. 3, p. 121 (S.).

ANON.—The Crompton-Chambers Conduit System.—*Lum. El.*, vol. 51, No. 2, p. 83 (I.).

A. WITZ—Experiments with a Crossley Gas Engine in connection with an Electric Light Station.—*Ibid.*, p. 84.

G. RICHARD—The Mechanical Applications of Electricity.—*Lum. El.*, vol. 51, No. 3, p. 112, No. 4, p. 160 (S. I.).

ANON.—Electricity in Public Works: Construction of the Port of Bilbao.—*Lum. El.*, vol. 51, No. 4, p. 177 (I.).

ANON.—The Development of Municipal Electric Supply.—*E. T. Z.*, 1894, No. 1, p. 1.

F. UPPENBORN—The Central Stations of Messrs. Siemens & Halske: No. II.—Copenhagen.—*E. T. Z.*, 1894, No. 1, p. 2 (I.).

DYNAMO AND MOTOR DESIGN.

G. RICHARD—Details of Construction of Dynamos.—*Lum. El.*, vol. 51, No. 1, 15, No. 2, p. 60 (I.).

F. GUILBERT—Methods of Coupling Non-Synchronous Multiphase Motors.—*Lum. El.*, vol. 51, No. 1, p. 28 (I.).

ANON.—Improvements in Dynamos for Direct Currents by the Fives-Lille Company (Dolivo-Dobrowolsky).—*Lum. El.*, vol. 51, No. 1, p. 30 (I.).

A. BANTI—Experiments on Non-Synchronous Single-Phase Motors.—*Lum. El.*, vol. 51, No. 2, p. 72 (I.).

Dr. BEHN-ESCHENBURG—Increase in the Number of Exciting Phases in the Production of Rotary Magnetic Fields.—*E. T. Z.*, 1894, No. 3, p. 35.

C. P. STEINMETZ—Multiphase Motors.—*E. T. Z.*, 1894, No. 4, p. 45.

MAGNETISM.

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ANON.—Use of Folded Cardboard as Insulation, &c.—*E. T. Z.*, 1894, No. 4, p. 49 (I.).

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2. The Library is open (except from the 14th August to the 16th September) daily between the hours of 11.0 a.m. and 8.0 p.m., except on Thursdays, and on Saturdays, when it closes at 2.0 p.m.

An Index, compiled by the late Librarian, to the first ten volumes of the Journal (years 1872–81), and an Index, compiled under the direction of the Secretary, to the second ten volumes (years 1882–91), can be had on application to the Secretary, or to Messrs. E. and F. N. Spon, 125, Strand, W.C. Price Two Shillings and Sixpence each.

JOURNAL

OF THE

Institution of Electrical Engineers.

Founded 1871. *Incorporated* 1883.

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The Two Hundred and Sixty-first Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, March 8th, 1894—Mr. Alexander Siemens, President, in the Chair.

The minutes of the Ordinary General Meeting of February 22nd, 1894, were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Francis Hastings Medhurst.

From the class of Students to that of Associates—

Frank Cobden Briggs.	A. G. Newington.
Cecil Charles Fowler.	Percy W. Paget.
Leopold William Heath.	Hastings Squire.
John Leggat.	Henry G. Wood.

Mr. C. C. Hawkins and Mr. J. T. Morris were appointed scrutineers of the ballot.

Donations to the Library were announced as having been received since the last meeting from Messrs. Alabaster, Gatehouse, & Co.; Co-operative Wholesale Societies, Limited; the Secretary of State for India; and Mr. W. H. Blakeney, Member; to whom the thanks of the meeting were duly accorded.

The following paper was then read:—

ON PARALLEL WORKING, WITH SPECIAL REFERENCE TO LONG LINES.

By W. M. MORDEY, Member.

Mr. Mordey. In his reply at the end of the discussion on his Niagara paper, Professor Forbes alluded* to some experiments which he had witnessed, and which he considered showed that alternators of my design would not run properly in parallel. The passage is as follows:—"At the time when I recommended the "Mordey machine I said that, before deciding to adopt it, "tests must be made with a resistance between the dynamos "in parallel. Does Mr. Mordey forget that, when he kindly "placed at my disposal the means of making this test, by "putting 'sunbeam' lamps in series—that is to say, between "the two dynamos working in parallel—the lamps went up "and down in brightness with the periodicity of a few "seconds, and that the tendency was to rise to maximum "brilliancy, showing that the dynamos were rather working in "series than in parallel? From the moment of those experi-"ments, I felt that that type of machine was not suited for our "purposes, though I never mentioned that, until I was compelled "to by Mr. Mordey's claims for his special mode of working." I heard his remarks with the utmost astonishment, as the experiments, rightly interpreted, appeared to afford the very strongest proof of the exceedingly powerful synchronising effort exerted by these machines, and because I then heard a contrary view expressed for the first time.

And in another passage Professor Forbes stated that they

* *Journal*, xxii., 607.

must have alternators at Niagara that will run without any synchronising or waste current. Mr. Morde

The matter is of some moment, and demands an explanation. With your permission, I will make this explanation the text and starting point of a paper on parallel working, and on the allied subject of the use of alternators as synchronous motors. The experiments were made in July, 1891, and were the subject of a leading article in the *Electrician* of July 16th, 1891, and were mentioned in the *Electrical Review* and elsewhere, in each case as having afforded an illustration of the thoroughly satisfactory parallel working of alternators when directly coupled to high-speed engines—a matter with regard to which there was at that time some uncertainty. It had been supposed that some flexible or yielding coupling was necessary between the engine and alternator. For my own part, I never had any doubt on the subject; but in order to place the matter beyond dispute some tests were carried out by the Brush Electrical Engineering Company and Messrs. Willans & Robinson. The former provided two of my alternators, the latter fitted them to two Willans engines. Amongst others, Professor Forbes received an invitation to witness the trial, and was present.

When all the tests of ordinary parallel working had been satisfactorily carried out—including shutting the steam off the engine driving one of the alternators, and then applying a brake to its fly-wheel in a vain attempt to force it out of step—a further test was made (as an interesting experiment bearing on the subject of synchronous motors) to ascertain what would occur if the two alternators were coupled together with a resistance between them so great that the resistance alone would be sufficient to absorb the whole power of one machine, even if the machine at the other end were at rest; and the remarkable fact was established that even under these conditions (which would be absolutely absurd or impossible in practice) the two machines did not break out of step.

The resistance used consisted of "sunbeam" lamps, which happened to be the only suitable resistance available. These lamps, being made for 80 volts and about 5 amperes, would have a

Mr. Morley. resistance, hot, of about 20 ohms each, and a much higher resistance when cold—probably more than 30 ohms. Seven of these lamps were placed in series between the alternators. There was no other external circuit. It was then found that there was a current passing through them which rose and fell with a slow pulsation; the alternators, although not actually breaking out of step, evidently getting a good deal out of true co-phasal synchronism, and only being pulled in when this slowly pulsating current rose to a considerable amount. Synchronism being regained, the current decreased again. This current was not measured, but was probably about 7 amperes, as the lamps were a good deal over-incandesced. The experiment was then discontinued.

Properly interpreted, this test appeared to show that, even when a line of an enormously high resistance was interposed between two alternators arranged to run in parallel (or one as generator, the other as synchronous motor), and when no adjustments were made to help them to keep together, the tendency to get out of step was corrected with a surprising amount of success; the correction, instead of being instantaneous and powerful, as with machines connected through a small resistance only, being sluggish, and greatly weakened by the effect of the very high resistance of the line.

To show how utterly unfair and unjust Professor Forbes's interpretation is, and to reassure those who may desire to use synchronous motors, it is only necessary briefly to examine the conditions of the test.

The two alternators used in the experiment were 37·5-kilowatt 2,000-volt machines. At full load each would therefore give nearly 20 amperes. Now, suppose it is desired to run one machine as a generator, driving the other as a synchronous motor (to take the illustration that may best suit the case of power transmission over a considerable distance), it will be seen that, if the line is to be designed to give such a percentage loss as is proposed for the Niagara–Buffalo transmission (that is, 3·5 per cent.),* the loss at full load should be 70 volts, and, the maximum current being, say,

* *Journal*, xxii., 516.

20 amperes, *the line resistance should be* 3·5 *ohms*. In the actual Mr. Morley experiment, the machines did not break out of step even when the line resistance was *more than* 100 *ohms*—that is, relatively more than 30 times greater than Professor Forbes proposes to use even for his long-distance transmission. This is the more striking as a proof of their powerful synchronising when it is considered that, even if it had been intended to expend the whole power of the generator in the line, that line should only have had a resistance of 100 ohms. That these machines did not act quite perfectly in parallel under these conditions, even with no load, is not to be wondered at. The only cause for surprise is that they exerted any sensible synchronising effort at all. It is exactly as if an attempt had been made to run two 1,200-kilowatt alternators in parallel through a line constructed to allow a reasonable loss for a couple of 40-kilowatt machines. Even unloaded, such a test would be unreasonable.

I now wish to refer to the "hunting," or regular pulsation of current, shown by the slow changing of the lamps from blackness to high incandescence, which is a matter of considerable interest. It may have been caused by self-induction, or, as, in this connection, it is sometimes termed, armature reaction—that is, the effect of the self-induced field produced by the armature in disturbing the impressed field of the field magnet. Although this effect may in some cases be considerable, I think we must look elsewhere for it in this case, because in the machines in question such reaction would have been inconsiderable, even if the phase relation had been most favourable to it. This I may illustrate by saying that if the armature current had been commuted, and passed round coils on the field poles having turns equal in number to the armature coils, the effect on the field would have been inconsiderable.

I think an explanation of the "hunting" will be found in the character of the resistance, and in the governors of the engines.

The change in the resistance of the lamps accounts largely for the pulsation. When black they would interpose a very high

Mordey. resistance—probably about 200 ohms—then, as the machine got a little out of step, the synchronising current would heat them, reduce their resistance, allow a much readier transfer of power, and so bring about a restoration of true synchronism, and a reduction of current through the lamps. This series of effects, being constantly repeated, goes a good way towards explaining the pulsation. Probably without this lowering of the resistance by the incandescing of the lamps, synchronism would not have been maintained at all.

Then, again, the governors of the engines must be considered. If they pulsated with the same period, but opposite phase, the action is explained; they would, at any rate, accentuate the "hunting," if they did not start it. Messrs. Willans & Robinson have kindly sent me an indicator card, taken by Mr. Willans at the time, which supports this view, the steam being shown as having been widely varied during the taking of the card.

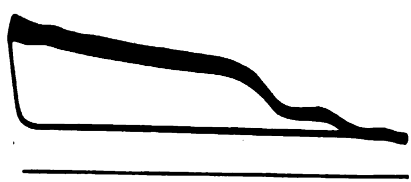


FIG. 1.

This must not in any way be taken as a reflection on the governors. The conditions were very trying for any governors, there being no load, and no opportunity occurred of specially adjusting them. If we had governed by hand at the stop valve, this "hunting" would not have occurred. Nor would it have occurred if we had adjusted the E.M.F. of one machine so as to allow it to run as a motor all the time. What happened appeared to be a repeated change in the functions of the two machines, from generator to motor—first one racing, and then the other, driving the second one as a motor.

The condition of entire absence of synchronising current or of correction can only be obtained by driving by engines that are very even in power always. I think this is more likely to be approached by turbines than by reciprocating engines. By

"synchronising current" I do not mean necessarily an actual current passing from one alternator to the other—this only occurs when one of them is driven as a motor—I mean the variations of the current contributed by each machine to the circuit. But I would like to point out that the condition laid down by Professor Forbes as an essential—namely, that they must have alternators at Niagara that will run without any synchronising or waste current—is an absolute impossiblity. Mr. Mordey.

Alternators will run without synchronising current only when there is no necessity for them to exert any synchronising effort. However, I am glad to find that Professor Forbes has set himself to solve this problem of getting an alternator motor to run without any current (for that is what it amounts to), because I am sure that in solving it he will also have disposed for ever of that other interesting problem—making a motor that will run without any back electro-motive force. This is a new and significant outcrop of the "perpetual motion" idea.

I am sure that if Professor Forbes had really considered or understood this matter he would not have expressed the opinion which I have quoted. At the same time, I wish to say I am convinced that his criticism was not unfair by intention.

The necessity for correcting a false impression has forced me to take the first opportunity of bringing this matter before the Institution. I regret that Professor Forbes is abroad, but he will of course have an opportunity of sending on for the *Journal* any observations he may wish to make.

It was not my intention to do more than make the above explanation, feeling sure that it would be sufficient to enable the Institution to form a correct judgment on the circumstances; but as I am permitted to occupy more of your time than I expected, I wish to refer to some tests that I have been able to make.

It appeared desirable to give the results of actual trials, preferably working one machine as a synchronous motor, and not merely as one of a pair of parallel connected generators.

It will be granted that the action of synchronous motors and of parallel alternators is very similar. But with regard to the

Mr. Mordey. trials just referred to it might fairly be argued that as each alternator had a steam engine behind it, on which it could fall back for assistance, something more is wanted to actually prove that the explanation is applicable to the case of a synchronous motor relying entirely on its own motor properties.

I am therefore glad to be able to place before you the results of some tests made in the works of the Brush Company.

Some Tests of a 25-Kilowatt Mordey-Victoria Alternator used as a Motor.

This test was carried out by my instructions on February 18th, 1891, four months before that witnessed by Professor Forbes.

A 2,000-volt 25-kilowatt alternator was run as a motor, driven by a 37·5-kilowatt generator. The motor drove a dynamo which was loaded until the alternator motor was taking about its full normal current, it being assumed that this represented full power. Separate tests* have proved this assumption to be justified. The following readings were taken with a resistance of straight platinoid wire between the machines :—

Test A.

Volts. Generator Terminals.	Volts. Motor Terminals.	Amperes.	Resistance in Line. Ohms.
2,340	2,002	13·74	32
2,358	1,932	13	48

The volts of the generator were raised above the motor volts sufficient to supply approximately the line loss.

This test was quite satisfactory, and of course settled, so far as we were concerned, any question that might at any time arise as to power transmission over long lines by synchronous motors—a matter that was from time to time coming up in connection with proposed installations. As a result, I always considered it quite safe to quote for work up to a line loss of 20 per cent. But, my attention being recalled to the subject by the extraordinary statements of Professor Forbes, I took the opportunity, after writing the foregoing explanation, to make some tests having a particular bearing on the details of the question before us. In some respects

* *Journal*, xxii., 127.

Mr. Mordey.

they are rather wanting in completeness—I was not always able to carry them as far as I wished—but I feel sure that you will approve of my supplementing my explanation by an account of such tests as the facilities at my disposal at the moment rendered possible.

TESTS OF 50-KILOWATT ALTERNATOR AS A MOTOR.

The object of these tests was to ascertain the effect of inserting resistance between two alternators one of which ran without load as a synchronous motor.

It was desired to find—

(*a*) What resistance was required to cause the motor to fall out of step;

(*b*) How much the current varied; and

(*c*) Whether any "hunting," or pulsation, was set up.

Two similar 2,000-volt 50-kilowatt alternators were used.

Generator.—This was driven by a separate engine capable of working it up to full load. It was run without governor, and controlled by hand at the throttle valve.

Motor.—This was started and brought up to synchronism by a small direct-current motor, driving by a belt which was thrown off as soon as the large motor was running synchronously.

The two machines were excited from a separate dynamo, their fields being in parallel.

The E.M.F. at the generator terminals was measured, and the current from armature to armature. The field currents were not measured, nor the E.M.F. at the motor terminals.

The generator was excited to give 2,000 volts, and then the motor field was adjusted till the current received by the armature was a minimum. This will be understood from Fig. 2, which is reproduced from a paper I had the honour of reading before this Institution last year.*

It may be remembered that I showed that there is a well-marked excitation that reduces the armature current to a minimum for any given load, and therefore gives a maximum power-factor and maximum efficiency. If the excitation be

* "On Testing and Working Alternators," *Journal*, xxii., p. 128, Feb. 23, 1893.

Mr. Mordey. varied on either side of that value, the armature current taken by the motor rapidly increases.

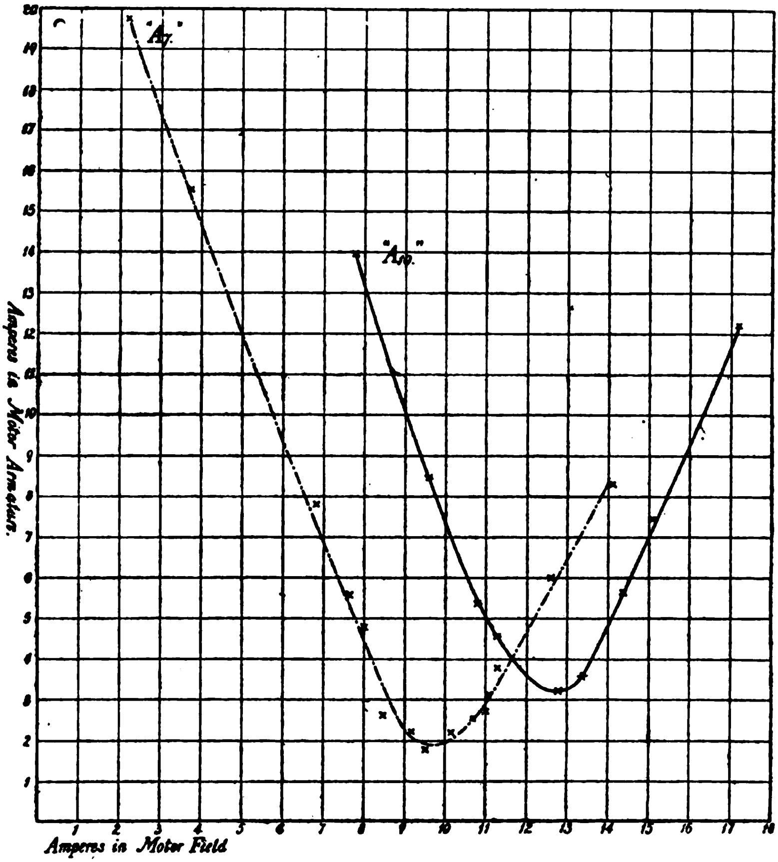


FIG. 2.

In working a motor it is desirable always to adjust the excitation till the bottom of this V curve is reached—that is to say, until the armature current is a minimum. In the case before us this current was found to be 1·6 amperes. Having got this, the excitation was not disturbed, and the following readings were taken :—

Mr. Mordey.

Test B.

Volts at Generator Terminals.	Current.	Resistance in External Circuit between Generator and Motor.	Remarks.
2,000	1·6	0	Current steady.
"	1·6	10	"
"	1·6	20	"
"	1·7	35	"
"	3·5	63	"
"	3·6	69	Current rather unsteady.
"	5·3	77	"
"	—	90	Current increased rapidly at this point, and the motor slipped quietly out of step.

In the first place, it is to be noted that there was no "hunting," or pulsation. The unsteadiness of the current was not regular.

Examining this test with a view to its practical aspects, it will be seen that it fully supports the explanation given at the commencement.

Applying to it a similar comparison, we see that, as the alternators were 2,000-volt 50-kilowatt machines, a line proper to these, in order to comply with the Niagara-Buffalo condition of allowing a loss of 3·5 per cent. in transmission, should have a resistance of

$$\frac{2{,}000 \times 3{\cdot}5}{25 \times 100} = 2{\cdot}8\ \omega;$$

and that the resistance of external circuit that would be sufficient to dispose of the whole load of the generator, supposing it to be merely working on that resistance as a load, would be

$$\frac{2{,}000}{25} = 80\ \omega.$$

Exactly as in the case of the trial witnessed by Professor Forbes, we find that a resistance of about 30 times a reasonable working amount had to be inserted before synchronism was interfered with, and it will be observed that more than 20 ohms had to be inserted before any effect appeared to be produced.

Mr. Mordey. But it may be said that the line loss, even with this enormous resistance, is comparatively trifling, as the current is not large, and that there ought to be plenty of power left to keep the motor in step. There *is* plenty of power, but it cannot be applied to the motor advantageously. The line loss, even with 5·3 amperes and 77 ohms, is only 408 volts and 2,156 watts (I am considering only resistance and current), whereas the generator was capable of supplying 50,000 watts. But it must be remembered that, the E.M.F. of the motor being kept up, it can only receive current under these conditions by letting itself get partly out of phase (and so into a disadvantageous position), and that then every increase of current intensifies the evil by causing a further loss of volts on the line, and therefore a further reduction in the E.M.F. impressed on the motor. Had I lowered the E.M.F. of the motor, or increased the E.M.F. of the generator, the line resistance could have been still further increased without loss of synchronism. Such a change of the relative E.M.F.'s of the motor and of the generator would have allowed current to get into the motor against the lower ordinates of its E.M.F. waves, without the necessity for any serious shifting of phase. If the motor E.M.F. had been lowered in this way the driving current would have increased, and synchronism would have been maintained much longer and through a higher line resistance, and would finally have been lost by the power being wasted in the line, and by "armature "reaction" on a weakened field.

Or, again, if the excitation of the motor had been raised, it should be found that it would go out of step with a smaller external resistance than before. This matter is of practical importance, as perhaps others than Professor Forbes may wish to work through a line 30 times too long, and therefore some tests were made to prove the truth of this explanation.

Test C.—The machines were run under the conditions of the fifth line of the readings given above—that is, with the excitation as before, and with an external resistance of 63 ohms, the current being 3·5 amperes. The excitation of the motor was then increased, probably about 20 per cent. Before there was

time to take any reading the motor went out of step. This was satisfactory as proving the correctness of the explanation. Mr. Mordey.

Test D.—Another test was made with the motor acting as a dynamotor in the manner shown in Fig. 3.*

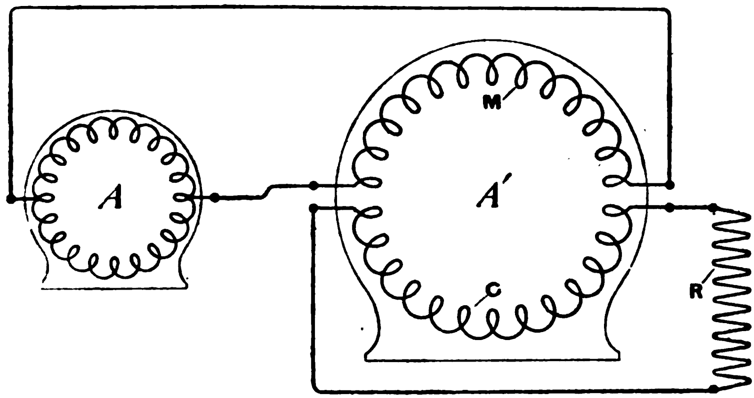


Fig. 3.

One half, M, of the armature winding was used as a motor; the other half, G, as a generator working on a separate circuit, R.

In this instance a load of 5 amperes and 2,000 volts was put on this generator portion, the lowest armature current being obtained with an exciting current of about 11 amperes. The field of this dynamotor was then reduced from 11 to 6 amperes, but it did not show any signs of getting out of step. The driving current rose to 15 or 16 amperes.

But on increasing the dynamotor field to 17 amperes it went out of step, the driving current being about 15 amperes. This test is not on all fours with the other, as there is the effect to be considered of the varying load on G, but it is a confirmation in a general way of the explanation.

Test E.—A test was then made to find, when working with no appreciable resistance between the machines, whether any "hunting," or pulsation, was set up by varying the excitation of the motor till the armature current rose considerably up either slope of the "V."

* Also reproduced from last year's paper.

Mr. Mordey. On decreasing the excitation till the armature current rose from 1·6 to 6 amperes the current became rather unsteady or irregular; the motor evidently getting a little out of step sometimes, and being pulled in by slight rushes of current of very short duration, which probably over-corrected the irregularity, causing the machine to run for an instant without current, or to act as a generator and itself to give current—that is, to act as an electro-mechanical fly-wheel, converting mechanical to electrical energy, and *vice versa*.

On increasing the excitation again, passing the bottom of the "V," and rising up the opposite slope to the same height (about 6 amperes), it was found that the current was rather unsteadier than under the conditions last noted; that is, when the current was about 6 amperes it was rather more unsteady in a strong field than in a weak field.

The explanation of this difference is that with a weak field the motor could receive current during its whole phase; whereas with a strengthened field the E.M.F. waves would be higher than those of the generator, and some want of co-phasal synchronism would be needed to allow current to get in.

In neither case was there any "hunting," or regular pulsation of current.

Some Tests of a 25-Kilowatt Alternator used as a Motor.

The motor in this case was arranged to drive a direct-current motor by means of which a load could be put on it that would be quite constant so long as speed was constant. It was desired—

(*a*) To find the effect of placing in the alternator circuit various amounts of resistance;

(*b*) To find the effect on the steadiness.

The 25-kilowatt alternator motor was driven by a 50-kilowatt alternator as generator.

Test F.—Motor was run with no load except its own direct-coupled exciter, and the direct-current dynamo, which in this case was run unexcited.

Mr. Mordey.

EFFECT OF REDUCING MOTOR EXCITATION AS RESISTANCE IN EXTERNAL CIRCUIT WAS INCREASED.

A. Generator. Volts.	A. Motor. Volts.	Amperes.	Line Resistance.	Remarks.
2,000	2,000	2·23	0	Current varying a little.
1,980	1,900	3·7	0	Current very steady.
2,040	1,900	3·5	65	„
1,960	1,840	2·0	65	„
1,950	1,820	2·23	75	„
1,960	1,800	2·0	85	„
1,960	1,780	2·23	95	„
1,960	1,760	2·23	105	„

We thus see a confirmation of what has been said about steady running being obtained, even with a very large resistance in the circuit, if there is a sufficient difference between volts of generator and motor. This is very common sense, and an experiment to prove it may seem superfluous.

The experiment was not carried further, as the resistance used was the greatest available at the moment. This light-load test should be read in connection with the full-load test A.

Test G.—A test was then made with a load on the direct-current dynamo. This load was 8 kilowatts, and was constant. Allowing for friction, and various losses outside of itself, the alternator motor was doing between 14 and 15 H.P.

A. Generator. Volts.	A. Motor. Volts.	Amperes.	Power Developed, about H.P.	Resistance.	Remarks.
2,040	2,040	7·0	14·5	0	Current fairly steady.
2,040	1,980	7·3	„	6	„
2,060	2,000	7·45	„	10	„
2,040	1,900	8·2	„	25	Current steadier.
2,040	1,740	9·8	„	35	Current steady.
2,120	1,540	11·0	„	45	„

Mr. Mordey. In this is seen the gradual increase of motor current as the motor volts get lower, while steadiness rather improves with the addition of length (or resistance) of line. The test is incomplete, because it was not convenient to put a larger load on, and therefore the motor was not worked up to full power; but it is confirmatory of Test A. It is interesting to observe, with regard to this test, that the idle current was very small. For example, the first reading of 7 amperes may be divided into 2·25 amperes needed to drive the motor and its exciter, and for friction of the direct-current dynamo (see Test F); and into 4·75 amperes for the added load of 8 kilowatts. The dynamo gave 8 kilowatts, and the motor received about 4·75 amperes × 2,040 volts = 9,690 watts. Allowing for the losses in the two machines, it will be recognised that the transformation was not only very fairly efficient, but that the power-factor was evidently high.

The relative lowering of the E.M.F. of a synchronous motor is a necessity in order to obtain good results in power transmission over long distances. In this way the necessity for self-adjustment by the motor of the phase relation is avoided, the motor being enabled to work (other qualities permitting) at its most advantageous phase relation. And the other advantages are retained of high power-factor (that is, a small idle current) and a high efficiency of generator, motor, and line. By this means it will be found possible to work such motors over very long lines, and with almost any desired line loss. It of course has its counterpart in direct-current power transmission, but there is a difference. In one case the speed varies and the field remains constant; in the other the speed remains constant and the field must be varied. It is not necessary to alter the excitation of a direct-current motor—its speed simply drops or rises until it has got the right E.M.F. With an alternate-current synchronous motor the speed cannot drop. The excitation must be lowered in this case to give the right E.M.F. Failing this, the motor will shift its phase in an endeavour to attain the same result. Of course in the direct-current machine the speed may be kept up by lowering the field.

SOME TESTS OF TWO 100-KILOWATT ALTERNATORS. Mr. Mordey.

Test H.—By the kindness of the City of London Co., I was enabled to make a trial with two of their 100-kilowatt alternators at Bankside, with the object of finding if, under the ordinary conditions of the station, these machines would work parallel with a considerable resistance between them and their load.

For this purpose a load of about 100 kilowatts was put on, and the two alternators were made to supply it through a resistance of 7·5 ohms in the external circuit of each. As this resistance corresponds to 37·5 per cent. line drop at full load, and 18·75 per cent. drop at half load, it is a fairly severe test. It was found that some lamps and a voltmeter placed across the load (a wire resistance) kept perfectly steady.

This, of course, was only a half-load test.

Test J.—When full load, or nearly full load, was on both machines, with 8 ohms in the circuit of each, there was a quite noticeable, but not at all violent, slow pulsation in the synchroniser lamp direct across the terminals of the alternators; but at the load the pulsation was very slight—barely noticeable. My impression was that with suitable adjustments this would have been quite a practicable arrangement—that is, to feed a lighting system from two alternators parallel, each having a 20 per cent. line loss between it and the load—a condition that is not likely to present itself very often.

Test K.—An attempt was then made to run the two machines parallel, with a load close to one of them, but separated from the other by a line of 16 ohms, corresponding to a line loss of about 40 per cent. The machines did not show any inclination to get out of step, but there was a pulsation of the E.M.F. at the lamps (at the load) of about 4 or 5 per cent. The result of this test, as carried out, was not good enough for lighting; although, f time and facilities had allowed, I think it quite likely that it could have been made satisfactory; but there was no pulsation or unsteadiness of a kind that would have interfered in any way with power transmission work.

It is a pleasure to me to make my acknowledgments to two

Mr. Mordey. assistants, Mr. Stobart and Mr. Foyster, who have ably aided me in connection with the recent tests and experiments, and to Mr. Watson in connection with the tests in 1891.

Some Analogies.

Probably I am not alone in having often found a difficulty in conveying, to persons not specially familiar with alternate-current matters, any very clear idea of the kind of action that takes place in parallel working. I would like, therefore, to be allowed to conclude by describing an analogy which I have often found useful in such cases.

Everybody knows something of toothed wheels.

To explain the relations of two alternators, separately driven, working parallel, imagine two engines driving by spur gearing on to a common shaft. The shaft represents the circuit from which power may be taken; the spurs, or teeth, represent the successive waves of current.

The operation of getting into synchronism is understood when one engine is imagined as running at its proper speed geared with the countershaft. To get the second engine to help, it will readily be understood that before being geared with the shaft it must be brought up to such a speed that the spurs of its toothed wheel synchronise with those on the shaft. A synchroniser, or phase-indicator, is the equivalent of a device for showing when the teeth of one wheel are exactly opposite the spaces between the teeth of the other wheel—that is, when they are synchronous. The mechanical process of slipping the two spur wheels together is the equivalent of electrically connecting the alternator and the circuit, and all the effects of doing this switching at the wrong time are easily illustrated by the sudden strain that would be imposed on the teeth. It will now be easy to follow the process of increasing the supply of steam to the engine until it transmits its proper proportion of power to the shaft; as well as the reduction of steam to such a point that the connection of either engine with the shaft (or of alternator with the circuit) can be interrupted at a time when no power is being transmitted from it or to it, and when, in consequence, its withdrawal makes no difference to the remaining engine (or

alternator) or to the countershaft (or circuit). The changing of load from one engine to the other is readily understood. Mr. Mordey.

Then the difficulties of parallel running may be made clear. Imagine one engine to get an insufficient supply of steam: it will be seen how the other must not only keep the countershaft (and any load) going, but must also drive the other engine. And note that this driven engine (receiving its power from the countershaft) is the analogue of the synchronous motor, and that the fact that the pressure is now not on the front side, but on the rear side, of the teeth, corresponds to the pull on the poles and armature coils being in the opposite direction to what it was as a generator; and that the difference of phase, or angle, between a generator and a motor is illustrated by this change in the relative position of the teeth on spur wheel and shaft. If the teeth of one wheel are exactly midway between those of the other, corresponding to exact cophasal synchronism, a line drawn through the tip of one bisects the hollow of the other; and driving is possible either way, in this position, only if there is absolute fit—that is, no lag or lead—no clearance either side. As this is not possible in practice, there is always a lead or a lag, corresponding to similar changes in the relative positions of field and armature in an alternator, as generator and as motor; this change of angle being also conveniently expressed or measured in terms of the space occupied by a pair of teeth or a complete period.

Then it is possible, by this analogy, to get an engine builder to see what happens when an engine runs at different speeds during parts of each revolution. He will see that, if two engines are in use, and one is slowing a little as it goes over its dead centres, while the other is getting steam and quickening a little, the teeth of the former will be bearing with diminished pressure on the teeth of the countershaft, while the latter will be exerting increased pressure. And he will see that, if this difference is considerable, the power may all have to be supplied by one engine, which may even have to drive the other engine as well—that, in short, each engine may in each revolution be alternately a generator and a motor, twice or oftener (according to the number and setting of the cranks).

Mr. Mordey. It will not be difficult to explain the pulsations of synchronising current transmitted through the circuit between the two alternators by the analogy of the impulses transmitted from one engine to another through the countershaft.

He will also understand why, if the engines have this defect, this interchange of power will not take place, and will not be required, if he so arranges matters that the connection is made at a time when the engines (supposing them arranged to run at the same speed) are in the same part of their stroke; but in this case, as the engines cannot correct each other's irregularities, the speed of the countershaft may have an objectionable want of evenness of running, affecting any machinery driven from the countershaft—that this difference will be less on the driven machinery if it is driven by belting, and therefore not necessarily synchronous, than if it is driven by spur gearing, and so forced to run at the same speed.

I will not stop to do more than suggest the comparisons that may usefully be drawn between weight of fly-wheel and of electro-magnetic inertia or self-induction as illustrating the effects in steadying the running of all shafts or circuits. But I cannot resist the temptation to show that, as with alternators in parallel the very rapid interchanges of power take place with scarcely perceptible resistance (that is, frictional) losses, it is conceivable that two such machines and engines will take less steam to drive them than if they are dividing the same load between them on separate circuits. That this increase in efficiency is a fact has been shown by actual tests, which I hope later on will be placed before you.

Then the analogy may be carried further, and an understanding may be imparted of the difference in the synchronising abilities of various alternators. To do this it is necessary to add to the analogy of spur gearing the idea of that gearing having teeth of various degrees of stiffness or rigidity, varying all the way from phosphor-bronze to yielding elastic material such as soft rubber. The former may be compared to the alternators having unyielding fields and small armature reaction; the latter to machines having poles the magnetism of which gives way, more or less, under pressure.

It will, no doubt, be difficult to get the uninitiated to grasp the idea of a tuft of lines of magnetic force from a pole-piece acting, through air, on a copper wire carrying a current, as corresponding to the material teeth of spur wheels geared together; but it is at least worth the attempt, and the result is usually better than the antecedent chaos. Mr Mordey.

Having conveyed this idea of various degrees of rigidity of teeth, as the equivalent of the various dégrees of synchronising efforts of which different alternators are capable, the next step is to explain why with alternators having magnetic teeth of the gelatinous variety it is possible to put them into parallel (or to gear them) when they are unsynchronous, without anything happening except a more or less complete temporary flattening of the teeth (or alternations) of both machines, corresponding to a temporary cessation of useful effort, until they have gradually worked themselves into phase. And it will be understood why with such machines any sudden alterations or strains should be avoided as likely to result in the bending down of the teeth, and loss of synchronism. On the other hand, it will be seen that, if the machines have strong and unyielding teeth (or powerful synchronising qualities), they will make a prodigious effort to keep in step whatever happens.

This analogy affords an explanation of the difference in the way in which the synchronising current circulates between alternators of the two kinds. With spur wheels of the strong type it will be seen that any transfer of power will be immediate and prompt, the correcting impulses being transmitted with decision and sharpness, the lagging or yielding permitted being only that due to the space between the teeth. This corresponds with the short, sharp impulses of synchronising current between two alternators of one type; while the slow and sluggish impulses of current between two alternators of the weak field type is understood by imagining what would happen with an attempted interchange of power between the two engines geared to a shaft by teeth of some yielding material.

A further analogy and I have done, to show those who are at all familiar with the mechanics of spur gearing how unnecessary

Mr. Mordey. it ought to be, so far as the machines are concerned, to reduce the number of magnetic teeth, or periods, in order to get satisfactory and smooth driving, either singly or parallel. It is only in cases where the electrical spur wheels are so designed that the teeth cannot get in, that a small number of periods can be of any service (so far as the machinery is concerned). Steady and smooth driving is rather to be sought in the other direction.

The President. The PRESIDENT: Gentlemen,—You have shown by your applause how much you have appreciated Mr. Mordey's paper, and now you can show by a very lively discussion that you also can give another expression to that approval.

Mr. Raworth. Mr. JOHN S. RAWORTH: It appears to me that Mr. Mordey is so full of alternate currents that he cannot be squeezed in any part of his frame without an immense amount of information oozing out of him. I am sure this Institution must feel deeply grateful to Professor Forbes for having trodden so severely on Mr. Mordey's toes, because the result of it has been that he has given us this most interesting academic paper. I do not know how it is that this Institution seems to be entirely dependent on Mr. Mordey for giving them experimental facts with regard to the working of alternators. There are some—I do not know how many—hundreds of our members who are continually giving us theories about alternate currents; but Mr. Mordey is the only one, as far as I remember, who gives us fully worked out experiments showing how alternating-current machines work either singly or in parallel. It is probably owing to the extraordinary facilities which Mr. Mordey has, in connection with the Brush Company, that he is able to make these experiments, and to bring them before this Institution; and I beg to suggest to other large companies who possess equal facilities, that they should be equally generous towards their *employés* in permitting them at times to place their results before this Institution. I do not see why the Brush Company should quite have a monopoly of this kind of benevolence. But, to come to the particular text which Mr. Mordey has taken this evening, and which has been the lemon-squeezer that Professor Forbes applied to him to get out of him the very

interesting paper we have heard to-night, the Brush Company have not by any means taken a serious view of Professor Forbes's statements. They are perfectly well aware that the dynamos they manufacture are not steam rollers, or water carts, or anything else of that character: they are made to work under certain conditions, and they do work under those conditions remarkably well; and the only statement Professor Forbes made concerning them was that they did not work, according to his view, to his satisfaction when they were coupled together by means of a number of incandescence lamps in series. I am not at all afraid of that allegation. As far as the commercial undertaking of the Brush Company goes, I care neither whether it be true or false; but, as it has made a text for Mr. Mordey to dilate upon, it has provided us with a most interesting evening, and I am very pleased we have thus received the information he has laid before us. I wish to point out that Professor Forbes in the first instance found a mare's nest, and that Mr. Mordey has taken a good deal of trouble to explain away that mare's nest, without exactly touching the actual bottom of it, though he has got very close to it. The peculiar circumstance or phenomenon which Professor Forbes observed was not an alternating-current effect at all. No question of alternating current need be raised to explain it, nor, for that matter, do we want any electrical currents whatever. We had on that occasion two dynamos working in parallel, driven by two similar engines running on their governors without load, and connected together by one of the thinnest connectors you can imagine. What happens under ordinary conditions with an engine running on no load and controlled by a governor? It always hunts. Every governor hunts. There is no such thing in the world as a governor which does not hunt, and there will not be until we get one which has no friction, because, before the governors can act, the change in the centrifugal force must be enough to overcome the friction of the governor. That friction is a definite amount, and therefore the change of speed must be a definite amount. That process is repeated up and down continually; and when we say the governor does not hunt, we

Mr. Raworth.

Mr. Raworth.

mean the changes are made so rapidly that we are unable to see the effect upon the speed by the eye, but the hunting is there all the same. What happened at Mr. Willans's works was this: Two governors were either both or one of them hunting. The steam would come on and carry the engine away faster, then the governor would shut down and the speed would drop—of course these variations being very small, but quite sufficient for the purpose. The one engine that was leading had to pull the other after it, through the very thin interconnecting link, *i.e.*, the electric current through a high resistance between the two motors. When the increase in speed ceased there was an exact balance of electro-motive forces between the two alternators, and the lamps went dead. When the speed of the first engine decreased the other engine had to pull it after it, and thus the cycle was repeated backwards and forwards. The same thing would have happened if there had been two continuous dynamos; the same would have happened if there had been no dynamos at all, and one engine had been put in front of the other, and the two fly-wheels connected by a very thin india-rubber band. First of all, the top of the belt would have run down slack and the other come up tight, and *vice versâ*; and the process would have been continued in regular pulsations, just according to the speed and pulsation of the governor. This mare's nest, when it is taken hold of, is nothing in the world but a common mechanical effect, and has nothing whatever to do with alternating currents. I said a moment ago we were never called upon to sell alternators to perform these peculiar functions of working in parallel with a big resistance between them, and only on one occasion have I ever heard of anybody but Professor Forbes who asked that such a thing should be done or tried. That was a case that you, Sir, mentioned to me yourself about 13 or 14 years ago—that you instituted certain experiments to ascertain whether alternators would run together in parallel; and you told me, with very great disgust at the failure of running parallel, that the idiotic operator had placed 70 ohms between the two alternators. That is the only other case there is on record, I believe, in which anybody ha tried to run alternators for any purpose with such enormous

resistance between them. Now I think I have made out, as far as the Brush Company is concerned, that we have no cause of complaint against Professor Forbes. He has not said anything against our alternators that we in the slightest degree object to. He has only done a thing that was once done before by a gentleman to whom you, Sir, objected in very strong language, and he has given us an opportunity of hearing one of the most interesting academic papers I have ever listened to from our friend Mr. Mordey. Mr. Raworth.

Mr. C. P. SPARKS: I wish to endorse Mr. Mordey's remark about running alternators in parallel. The principal difficulty is to secure steam engines which will give us an equal turning moment. If you take an ordinary single-cylinder engine, or even a compound engine with a fly-wheel of ordinary proportions, and either drive your machine direct or with rope gearing, on putting machines suitably proportioned into parallel a certain synchronising current is needed to keep these machines in parallel; in the case of direct-driven machines the synchronising current is generally larger than with rope driving. That current wholly depends upon the equal turning moment and the inertia of the moving parts; and if the angular velocity varies very much during a revolution, we find a very large current is necessary to keep any two machines coupled together. When the dynamos are rope-driven, the rope acts as a flexible coupling between the driven and driving parts; thus the synchronising current is reduced. The conditions of parallel running are often aggravated, as mentioned by Mr. Raworth, by governors. All governors hunt, through friction in their working parts; and even when we have a governor with a very small amount of friction, it always has the effect of increasing the synchronising current by a sensible amount. Mr. Sparks.

The difficulty of securing an equal turning moment is got over by having the shaft driven by several cranks set at the proper angle to one another. When we take a compound engine with cranks at 90 degrees, we certainly get a better result than by having a single-cylinder, or a compound with cranks at 180 degrees. In coupling large alternators together it is advisable

Mr. Sparks. that there should at least be two high-pressure, if not three high-pressure, cylinders working on the same shaft, with cranks distributed round the crank path so as to get a very equal turning moment, in order to prevent the enormous strain placed upon the armatures of the dynamos in trying to correct the irregularities of their respective steam engines against the inertia of the moving parts: the strains thus produced prohibit some types of alternators from parallel running. Of course, if we use a very heavy fly-wheel, we modify the amount of work done by the armature; but it is impossible in many cases to put on a sufficiently heavy wheel to obviate the strain placed on the armature.

Mr. Weekes. Mr. R. W. Weekes: The purely mechanical explanation of the pulsation in the current given by Mr. Raworth does not appear to be satisfactory. Obviously the speed of both engines must be the same, and the governors can therefore not hunt independently. On the other hand, Mr. Mordey's own explanation, based on the varying resistance of the lamp circuit, is in itself sufficient to account for all the effects observed.

Mr. Kapp. Mr. Gisbert Kapp: I should like to echo the remarks of Mr. Raworth, as far as they refer to the value of the paper, and especially to the educational value of the analogies given at the end of the paper. It is an exceedingly happy simile to compare alternators working in parallel with spur wheels running in gear. There is, however, one correction I should like to make in the author's method of representation. That is, in his comparison between teeth of different stiffness. He contrasts spur wheels with flexible teeth with those having stiff teeth, to the disadvantage of the former. As the paragraph reads, one would be inclined to think that the idea of flexibility carries with it the idea of a weaker tangential force acting between the two wheels. If that were so, then undoubtedly the stiff tooth wheel would be better; but there is no reason to suppose that the flexible tooth is not equally strong: it yields a little, but the more it yields the greater force it exerts. Therefore it is perfectly compatible with the simile to imagine the two wheels having teeth of equal strength, only one tooth will yield through

a certain distance before it attains that tangential force, whereas Mr. Kapp. the other does not yield at all and attains the tangential force at a blow. For this reason I have always been an advocate of having machines with a certain amount of self-induction. Such a case represents spur gear with elastic teeth, whilst the case of machines with exceptionally little self-induction is represented by spur gear with hard teeth. When such machines are put in parallel, or if one is accidentally short-circuited, the armature coils are subjected to very hard blows, and this may lead to the machine being ripped to pieces.

Before I speak about the very interesting subject of power transmission through long lines, I should like to draw Mr. Mordey's attention to what I am afraid is a misprint on slip 6, where, at the bottom, he says: "On increasing the excitation "again, passing the bottom of the 'V,' and rising up the opposite "slope to the same height (about 6 amperes), it was found that "the current was rather steadier than under the conditions last "noted." But then he goes on to say: "When the current was "about 6 amperes it was rather more unsteady in a strong field "than in a weak field." Should it not mean more unsteady in a weak field than in a strong field? There is a contradiction in that paragraph as printed in the slip.

The author's experiments were undertaken and brought to our notice with a definite object—viz., to show that Professor Forbes's objection was not a proper one, not one which occurs in practice, and was, moreover, not so detrimental to the working of the machine as he made out. But I think Mr. Mordey has not done himself justice. The experiments were made on motors running light. In one or two cases there is a load mentioned, but it is a small load for the size of the machine. Had Mr. Mordey really treated the machine as they would be treated in power transmission,—had he put a mechanical load of 50 kilowatts on the 50-kilowatt alternator,—he would have found it to drop out of step very much sooner than it did. I should like to say something in connection with these "V" curves, which are exceedingly useful curves if you draw the whole of them. The curve is useful because it shows exactly the point at which

Mr. Kapp. the machine will drop out of step. In a transmission plant where the resistance in circuit is small and the self-induction large, the left branch of the "V" very soon becomes vertical, and then curves over to the right; whereas the right branch of the "V" slopes out to a very great distance—in fact, so far that the machine could not take the great current which this branch would indicate as possible, because it would get too hot. In a plant of that kind it would be best to excite the motor a little above the point which Mr. Mordey rightly considers, theoretically, the best point—that is, the bottom of the "V." The curves given in the paper were taken with machines running light, and do not represent the true shape. To each load on the motor corresponds one particular "V" curve; and the greater the load the more rounded, generally speaking, become the two branches of the curve, especially the left branch. If, therefore, you have a transmission where the resistance is small, and where for some reason you have chosen equal machines with fairly large self-induction, it is advisable to excite the motor higher than the generator, in order that you may be working on that branch of the curve which slopes up to the right. If, on the other hand, you have the bad conditions that Mr. Mordey artificially produced in order to show the impracticability of Professor Forbes's requirements—viz., that you have a large resistance in circuit and little self-induction in the machines—the shape of the "V" curve is entirely different. In such a curve the left-hand branch slopes very much more to the left—in fact, becomes concave to the horizontal axis—and then curves back to the right, whereas the right-hand branch very quickly turns over to the left. The point where the branch turns over shows the point at which the machine drops out of step, and this point is reached with a very slight over-excitation. If, then, the resistance in circuit is abnormally great, you would, as Mr. Mordey rightly says, have to work the motor at a lower excitation than the generator; but in general when we use alternating currents for power transmission we are not under the necessity of wasting much power in the line, because we have the option to raise the voltage to such an amount that we can work with a very small

line loss. In that case the motor should be excited at least to the same pitch as the generator—preferably a little more—to get a fairly large margin of power. Such a margin is obviously necessary, because for short periods the nominal load on the motor may be considerably increased. In this connection I may mention a power transmission in Chur, Switzerland, where my machines are used. The plant was put up by the Œrlikon Engineering Works, and the motor is a 60-kilowatt machine which drives a mill. There it was found that to provide against the sudden strains when shafting is thrown into gear a considerable margin of power is required. This the motor is perfectly able to furnish. But if the line resistance were high no such margin of power could by any possibility be obtained. It is for this reason that I consider Professor Forbes's demand for machines which shall transmit and receive power through lines of abnormally high resistance an impracticable one. Mr. Kapp.

Mr. Mordey puts the limit of loss in the line at 20 per cent., but I should be inclined to put it at 10 per cent., so that a reasonable margin of power over the normal power of the motor may be secured.

As regards the question of parallel running of alternators, I think we have heard enough of the contention that certain alternators will run in parallel and others will not. It is not a question of the alternator at all; it is a question of the engine, and I can illustrate this best by our experience in Bristol. When Mr. Preece and I designed the Bristol station we were perfectly aware that a very even turning couple exerted by the engine is the only and the necessary condition for successful parallel working, and in order to fulfil that condition we specified engines with three cranks. The sets consist of Willans engines and Siemens alternators, and when the cut-off in the three lines of cylinders is properly adjusted there is no sensible synchronising current between any of the machines (two 88-kilowatt and two 210-kilowatt at present installed). Even when running light there is hardly sufficient deflection of the needles of the ampere-meter to take a reading. When running loaded the needles remain perfectly steady. These engines have three cranks, set 120 degrees

Mr. Kapp. apart, so as to give the most even turning moment possible, and the expansion gear on each line of cylinders is separately adjustable by hand. To get the greatest economy the expansion is occasionally adjusted so as to correspond with the load. If it were possible to alter all three expansions simultaneously, the parallel running would not be interfered with, and the needles of the ampere-meters would remain free from vibration. But as the expansions must be adjusted one at a time the turning moment of the engine becomes slightly uneven during the alterations. The effect of this unevenness is seen immediately on the instruments, the needles beginning to vibrate, and the vibration only vanishes after all the three expansions have been adjusted equally. The vibration is never very great, and has no effect on the current flowing out of the station. I merely mention this matter as an explanation of what Mr. Sparks said. I may mention that, although the machines have more self-induction than Mr. Mordey advocates, their synchronising action is very powerful, and this was proved accidentally some time ago when two machines were put in parallel whilst opposite in phase. There was a momentary howl of the machines, which very soon subsided, and the machines settled down into parallel without any trouble. This experience was quite satisfactory, though only the result of one of the connections of the synchroniser having been accidentally reversed. Of course in regular work the machines are put into parallel when the phases are equal. Accidents, however, will happen in the best-regulated lighting stations, and for this reason I think it of the greatest importance that the machines should be so constructed as to stand the rough usage which may result from such accidents. It should, for instance, be perfectly safe to short-circuit an alternator when running at full voltage, and this is safe provided the machine has a reasonable amount of self-induction. If it has too little self-induction, then the result of a short-circuit, or of such an accident as I have just described as having happened at Bristol, would be a general ripping out of the armature coils.

Professor Thompson. Professor SILVANUS P. THOMPSON: I had hoped we might have had some further information from those who have been manu-

facturing alternators and running them on a large scale. We certainly desire to have further data to discuss, particularly as to the question of the transmission of power from one alternator to another through a line of measurable resistance—a line which of itself absorbs any considerable fraction of the power. I think something more will have to be done on this matter, in spite of Mr. Kapp's remarks. Do I understand, in the case he referred to, that the alternators used were similar machines? Professor Thompson.

Mr. KAPP: Yes.

Professor S. P. THOMPSON: In that case I can understand the bearing of it; but surely cases will arise when we shall not use similar machines at the two ends,—where we shall design a motor to work specially at the end of the line in which there is to be allowed a measurable drop in voltage. In that case probably it will be advisable not to have the same degree of saturation of magnets in the motor as in the case where the machines are absolutely similar. As with continuous-current machines, when you have to design a power transmission from one machine at one end to another at the other, you do not make them exactly alike: you design them to run at different voltages; you design the armature of the motor with fewer windings, and the magnet of the motor has to be more highly magnetised than the magnet of the generator.

I wish to thank Mr. Mordey for the admirable way in which he has worked out the analogy of the toothed gearing. With respect to Mr. Kapp's criticism as to the flexible teeth being quite as capable of driving well as the rigid teeth, may I point out the reason why the flexible teeth in the electrical case are not so good for driving as stiff teeth is that the very property of flexibility is, not that there is a yielding, but that the yielding makes the tooth less strong: that is to say, those machines which have a feeble magnet that can be reacted upon by the armature do not simply yield in phase, but their magnet is weakened by the reaction of the armature, and therefore the tendency to synchronise is lessened; they actually cease to have the same force of return.

Mr. KAPP: They are strengthened if you over-excite.

Professor Thompson

Professor S. P. THOMPSON: In the motor, not in the generator. There are some other ways of synchronising than those adopted in this country. I should like to know if anyone can give us any information as to the use of those horrible things used in America called "acoustic synchronisers," which howl alternately when the machines are out of phase. Also, if anyone has had any experience of a purely optical synchroniser attached to the machines. I remember very well watching the machines built by Ganz & Co. in the station at Rome. The alternators were set in one line. You can look through one machine at another, and you can see when the machines are synchronised by merely observing the rotating magnets of one machine across the rotating magnets of the other. They will appear to be stationary when absolutely in phase, just as two perforated discs of cardboard with holes when they spin round at equal speeds; one being watched through the holes in the other. It is quite possible, I think, that some optical synchroniser might be found which would be more satisfactory than either the acoustic or the electrical synchronisers with lamps. Lastly, I would ask if anybody has any information on the use of common steam supply to the engines which are driving the machines that are to be put in parallel or which are running in parallel. It seems to me that a good deal in the easy working of two engines together may depend upon the question whether their steam supply is in common. Suppose a load is increased on a sudden where there are two alternators on the omnibus bars, it is desirable, probably, that both those alternators should share in the increased load. If they are running with governors, you have to wait for both these governors to open the valves a little more. Something has to happen independently, as it were, on the two machines; whereas, if they were fed from some common valve, we might have a different condition, and one more suitable for keeping the machines absolutely in phase with one another. I remember when Mr. Mordey first brought this matter of parallel running before us in that remarkable paper of two years ago, I begged him to tell us, when he replied to the questions, in what way the two engines were governed which had shown such remarkable success in running parallel; and I elicited the information that

there were no governors at all on the engines, as, indeed, I rather suspected. In many stations we know governors are not used; that is to say, though there may be the governors on the engines, they are arranged so as not to come into operation in ordinary working. Very little seems to be recognised as accepted practice on this matter, and it is most desirable that we should have an expression, not only of opinion, but of actual experience gained in different stations with different makes of engines, with different types of governors, with different types of alternators, as to the conditions under which machines run most satisfactorily in parallel with one another. Professor Thompson.

The PRESIDENT: The discussion will now be adjourned until our next meeting, which will take place on the 29th inst.

I have to announce that the scrutineers certify that the following candidates have been duly elected:—

Members:

Sidney Howard Farrar.
Claude William Hill.

Associates:

Arthur Hinton Allen.
John Edward Dane.
F. R. Davenport.
James Livsey Dyson.
John Charles Dwyer.
John R. Gall.
Cecil W. Gwyther.
Owen M. Jonas.
Enrique W. Martin.
Joseph Horsnell May.
Alexander Moir.
Edward B. Pym.
J. Clifton Robinson.
Sherley Sherley-Price.
Dudley Stuart.

Students:

Frederick W. Dalton.
Edmund J. Fox.
William James Grey.
Percy George Rathbone.
Ernest Sherley-Price.
R. E. Skipwith.
William Frederick Stuart-Menteth.
Charles F. Wilkin.

The meeting then adjourned.

The Two Hundred and Sixty-second Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, March 29th, 1894—Mr. ALEXANDER SIEMENS, President, in the Chair.

The minutes of the Ordinary General Meeting of March 8th, 1894, were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Professor W. H. Bragg.	Henry John Vose.

From the class of Students to that of Associates—

William A. Brodie.	Percy W. McDougall.
Herbert George Crabb.	Harold George Rea.
Victor J. Delebecque.	Harold H. Simmons.
Archibald Henry Finlay.	William Henry Slater.
Bernard Booth Granger.	Sidney Charles Watson.
Arthur Llewellyn Lean.	Alan Williams.
Alan P. McDouall.	Claude H. C. Woodhouse.

Mr. F. H. Taylor and Mr. A. G. Seaman were appointed scrutineers of the ballot.

The PRESIDENT: A copy of the balance-sheet has been sent to each one of you, and I would therefore propose—"That the "balance-sheet be taken as read."

This was agreed to.

The PRESIDENT: I beg to move—"That the statement of "accounts for the year 1893, as just read, be received and

"adopted." Before I put this motion, I would inquire whether any member has any question to ask, or desires further information on any point, in which case the Secretary or myself will be very glad to reply.

No questions being asked, the motion was seconded by Mr. W. R. RAWLINGS, and, having been put from the chair, was carried *nem. con.*

The PRESIDENT: We will now resume the discussion on Mr. Mordey's paper, "On Parallel Working through Long Lines."

General WEBBER: I had not the benefit of hearing the discussion on Mr. Mordey's paper, although I have read it, and, I may say, was much struck with the analogy with which that paper terminated. General Webber.

But there is one example of parallel running as to which it seemed to me to have been a regrettable omission on Mr. Mordey's part to have said nothing, upon which I think he ought to have been able to give us information—one that has been going on for a considerable time under some of the circumstances which he describes, and which might have afforded data that would have been of even more interest than those which he mentioned.

For two or three years it has been known that Mordey-Victoria alternating-current dynamos have been guaranteed to work perfectly in parallel with any other dynamo of the same make, irrespective of size; and the description of the experiment which Mr. Mordey mentions as having been made by him, with the permission of the City of London Company, at their Bankside station, is only a description of one under those well-known and guaranteed conditions. Now, although it is common knowledge that for a very considerable time the City Company have been running in parallel not only Mordey-Victoria dynamos, but also one or more of that make, and one or more Thomson-Houston machines of a different size and capacity, supplied and fixed by Messrs. Laing, Wharton, & Down, at a station known as the City of London Electric Lighting Pioneer Station, at Wool Quay, in Lower Thames Street, no mention is made by Mr. Mordey of such a condition of

General Webber. things, although, as electrician to the contractors for the City Company's Bankside station, on the Surrey side, he ought to be fully alive to the circumstances. The distance by cable between the machines is close upon 2,500 yards. Those generating units differ, as you know, not only essentially in the construction of the dynamos, but also in the motors which are driving them. The Brush—*i.e.*, the Mordey-Victoria—dynamo, as Mr. Mordey told you, is a 100-kilowatt machine, and is driven by a Brush-Raworth vertical engine, the speed of which is about 167 revolutions; and the Laing, Wharton, & Down, or "Thomson-Houston high-tension, "composite field, automatic, self-regulating, alternating-current "dynamo," has a capacity of 120 kilowatts, and is driven by a Marshall's engine, with a speed of about 170 revolutions. Those two generating units are, as I have said, placed in stations 2,500 yards apart by cable measurement, and they are both serving the primary circuit of one bank of transformers. It is essential that those dynamos should be running in parallel, so far as can be achieved under the circumstances as described by Mr. Mordey. Therefore my remarks will go no further than to take the form of a question, and express a hope that the facilities which Mr. Mordey obtained from the City of London Company, for what might be called a laboratory experiment, may also be given to him, if he has not got it already (I rather think he has), as to this extremely novel and practical state of things which has been now in existence at our very doors for nearly twelve months, and with such success, I understand, that in at least one case the generating units serving from one or the other source have had suddenly to take the full load. What adds to the probable interest of such information is that the phases of the two dynamos were originally different—namely, 100 in the Mordey, and 130 in the Thomson-Houston. Of course this difficulty has been overcome, but I am not in a position to say how it has been done, although we all know it is not a very serious matter.

Capt. Sankey. Capt. H. R. Sankey: I would like to take this opportunity of confirming what Mr. Mordey said with reference to the ease with which the two Mordey alternators, coupled direct to Willans engines, could be run in parallel at the experiments at Thames

Ditton. There was not the slightest difficulty in putting them into parallel, nor was there any sign whatever of their trying to get out of step. Moreover, everything that could be thought of was done to get them out of step, but without success, with one exception. A brake was put on the fly-wheel of one of the sets, with the object of reducing its speed, and it was found that the speed of the other set was equally reduced, as if they had been mechanically geared together. In this manner the speed of both sets was gradually lowered, until it was only 25 revolutions per minute, when at last they got out of step. The set on which there was no brake then ran up to about 500 revolutions, and the other remained running at 25 until the plank which was used as a brake had been removed. I cannot speak, unfortunately, so positively about the "sunbeam" lamp experiment—the experiment that forms such an important part of this paper—neither can any members of the testing staff at Thames Ditton give any information. The fact is there was an idea that this experiment was a private one between Professor Forbes and Mr. Mordey, and for that reason practically no notes were taken. I went through all our records at Thames Ditton, at Mr. Mordey's request, and the only thing I found was the indicator card which is reproduced in Mr. Mordey's paper (see p. 264), and which had some notes on it in Mr. Willans's handwriting. As regards the cause of the pulsation in the light of the "sunbeam" lamps, I am inclined to agree with Mr. Mordey's first supposition—that it was due to synchronism between the changes of load *on the engines* and the time-period of the governor, so that a disturbance once set up would continue. I do not think it was due to hunting of the governors; and this view of the matter is confirmed by Mr. Low, who had charge of the engines, and is perfectly certain that their governors were not hunting. The indicator card above alluded to would no doubt be produced if the governor was hunting, but it would also be produced if the governor was not hunting, but was sufficiently sensitive to follow up rapid changes of load—such changes as might be produced by the pulsation in question. This card is therefore no proof that the governor was Capt. Sankey.

Capt. Sankey.

hunting. To put the matter beyond doubt, I took some indicator cards this morning. I first of all took a diagram when the engine was working with a perfectly steady load on the dynamo of 81,600 watts, and running at 372 revolutions. The indicator pencil was held down for half a minute, so that more than 180 indicator diagrams were superimposed one on top of the other, and the engine was running so steadily that the result looks like an ordinary indicator card, as shown in Fig. A. The load was then varied backwards and forwards from 87,000 to 79,500 watts, including intermediate loads, by means of a stepped shunt resistance, at the rate of about 30 times a minute, and the resulting indicator card—the pencil being held down as before for half a minute—was identical with that shown by Mr. Mordey in his Fig. 1 (see p. 264), as will be seen from Fig. B. The governor was then put out of adjustment so as to hunt, which was found to be a somewhat difficult thing to do. The indicator card produced (Fig. C) was

FIG. A.

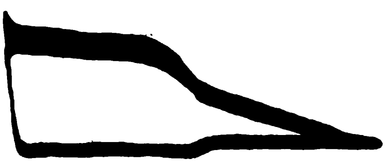


FIG. B.

FIG. C.

precisely similar to the one obtained with the varying load, and it would be quite impossible by merely looking at the cards to tell which one was due to hunting of the governor, and which to varying the load. I then thought it might be of interest to ascertain how sensitive the governor was, and for this purpose, after readjusting it, a definite change of load was made at different rates by varying the shunt as before. First the load was changed from 82,000 watts to 76,000 watts, and back again to 82,000, ten times a minute, and the card reproduced in Fig. D was obtained; then various higher rates per cent. were tried, with the same result, until the rate reached 192

changes per minute, and still there was a distinct fluctuation in the card, as shown on Fig. E, thus proving that the governor was Capt. Sankey.

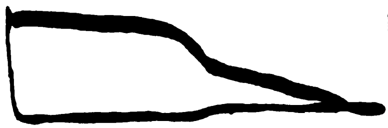


Fig. D.


Fig. E.

sensitive enough to easily follow and act on changes of load occurring at such extremely short intervals as one-sixth of a second. As regards the resistance of the "sunbeam" lamps—a point which Mr. Mordey referred to—I measured the resistance of one of them, cold, by Wheatstone bridge, and hot, at varying degrees of incandescence: the results are given in Fig. F.

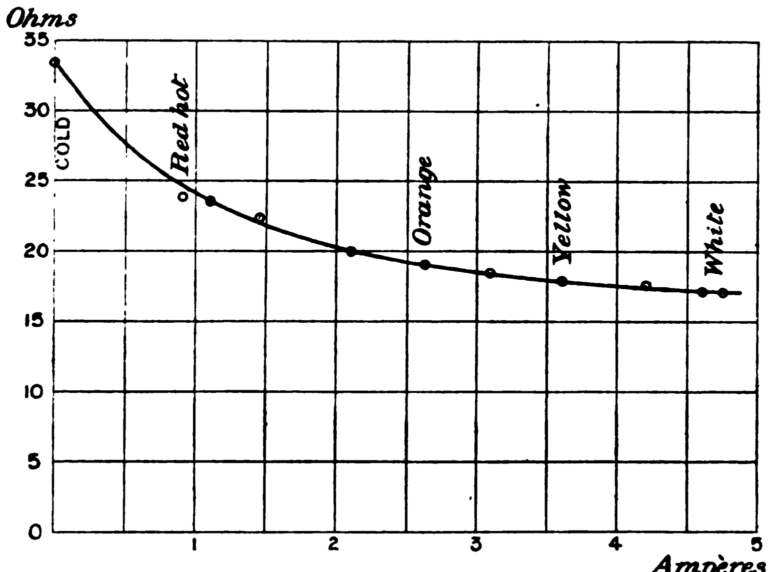


Fig. F.

I had not the pleasure of being here at the last meeting, but understand that Mr. Raworth said that the whole of this fluctuation was a mechanical effect due to hunting of the governors, and that so long as there was friction there must be hunting in governors. Now it is quite certain that there are governors that do not hunt, and it is also

Capt. Sankey.

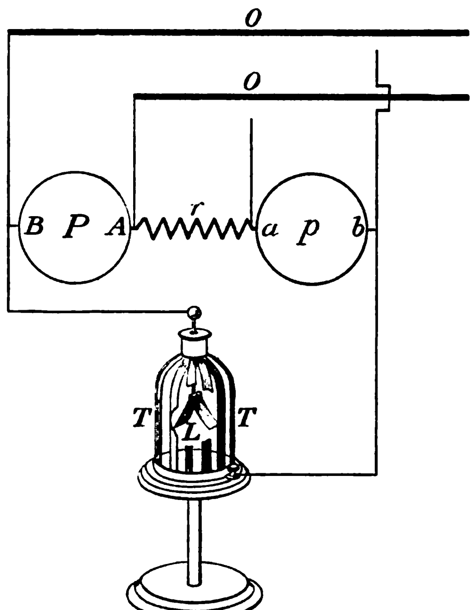
equally certain that those governors must have some friction in them. No doubt friction is a very usual cause of hunting in governors; but it depends more on where the friction is than on the amount, and it is only necessary to observe a certain minimum proportion between the power of the governor and the friction. There are also many other causes which will produce hunting. For instance, a curious injector action sometimes takes place with a badly designed throttle-valve, causing periodic variations in the pull on the throttle-valve rod; and there may be also a synchronism between the time-period of the governor (the system of the balls and springs being looked upon in the light of a pendulum) with the changes in turning effort of the engine, or even—exceptionally—with waves of pressure in the steam pipe, looked upon as an organ pipe.

Referring again to the "sunbeam" lamp experiments, I believe they were carried out on the spur of the moment at the request of Professor Forbes; and no doubt, had Mr. Mordey foreseen their effect, he would have wished to have continued the experiments until he had found out the cause of the pulsation in the lamps. Possibly it might meet his views to repeat those experiments; therefore I would make this proposition: If Mr. Mordey will send to Thames Ditton a couple of 30-kilowatt alternators of his make, they will be coupled up direct to two Willans engines, and we can try experiments until this matter has been thoroughly threshed out; and the result, whatever it may be, can be reported to the Institution.

Professor Ayrton.

Professor Ayrton: At the last meeting the discussion turned somewhat on methods of synchronising alternators, and I will say a word or two on that subject. The ordinary method of synchronising alternators is, of course, familiar to you all. You have a transformer wound with two primary coils and one secondary coil. The currents passing through the two separate primaries are produced by the two alternators, and their resultant action is seen from a glow lamp inserted in the common secondary. Now all this elaboration of a specially wound transformer can be dispensed with if electrical engineers will condescend to deal with the pressure at the terminals of their

own dynamos, instead of always transforming down before making a measurement; and if they will also use electrostatic instruments instead of electro-magnetic—electrostatic, I say, because if electro-magnetic instruments were used in the way I am about to describe it would require that the two alternators should be electrically joined together before they were synchronised, and, naturally, electrical engineers would object to that. Professor Ayrton.



Supposing we have any two alternators, P, p; one of them, P, being already attached to the omnibus bars, O, O, supplying current to the outside circuit, and the other alternator, p, having to be brought into synchronism with P. Then the following is an arrangement which Mr. Mather and I have thought out:—Join one terminal, A, of one alternator, P, to one terminal, a, of the other alternator, p, not necessarily through a low resistance, which an electrical engineer might object to, but through a high resistance, r—as high as 20 megohms if you like: the very finest pencil line drawn on a piece of ebonite or slate will be a good enough electric connection for our purpose. Next connect the other terminals,

Professor Ayrton.

B, *b*, of the alternators to the binding screws of any electrostatic voltmeter—and I am using the word now in a most comprehensive form—an electroscope, a vacuum tube, anything you like which *electrostatically* indicates a large P.D. You may use, for instance, an insulated electroscope. You do not want the leaves to be made of gold leaf; tinfoil leaves will do, and they need not be small, like the ordinary leaves of a gold-leaf electroscope; they may be even a foot and a half long. Then, since the leaves are attached to the terminal *B* of one of the alternators, and the tinfoil outside coating of the electroscope *T* attached to the terminal *b* of the other alternator, the divergence of the leaves indicates the P.D. between the terminals *B* and *b* of the alternators. But the other terminals, *A*, *a*, of the alternators are electrically connected by a conductor which, although of high resistance, is quite able to keep these terminals at the same potential. Hence the divergence of the leaves of the electroscope at any moment is a measure of the extent to which the alternators are out of phase.

If the alternators each generate 2,000 volts, then, as the second alternator is speeded up, the P.D. between the leaves and the outside case of the electroscope will vary between 4,000 volts and zero, being 4,000 volts when the alternators are exactly opposite in phase, and zero when they are exactly in phase. At first the leaves will open out and shut up rapidly, then they will open and shut up more slowly, and, finally, they will stay closed up for an appreciable time. At that moment throw the alternators into parallel.

The arrangement is far more dead-beat than a glow lamp, for, of course, the luminosity remains for some time in the lamp. It is an apparatus which can be constructed very cheaply, and will cost far less than a specially wound transformer with three circuits on it. It may be made as large as you like, so as to be easily seen from a distance. You want no scale, no accurate calibration.

It does not matter whether this synchronising electrostatic voltmeter reads accurately to 1 per cent. or 10 per cent. or 20 per cent. The instrument may therefore be as wrong as you like, looked at from the point of view of an accurate electro-

static voltmeter. All that is needed is an electrostatic gauge which shows a large divergence at 4,000 volts, and no divergence at all for zero P.D. The arrangement is simple, cheap, quick in acting, and perfectly safe, for its use does not require you to connect the alternators together, therefore there is no fear of one dynamo damaging the other. We have practically employed this arrangement in my laboratory, and find that by its use two alternators can be sychronised with perfect ease and certainty. The electroscope employed was an ordinary one with small *tin-foil* leaves, but not one with leaves a foot or more long, such as I should construct for a central station, so that they could be easily seen from a distance. But that, of course, does not affect the principle of this synchronising device. Professor Ayrton.

The method is, indeed, so simple that, were it not that we have never seen it used in any central station that we have visited, nor seen it described or even referred to in any of the technical papers, or descriptions of central stations, we should have imagined that the idea must have occurred to others.

Prof. GEORGE FORBES [*communicated*]: The working of alternators in parallel, or as motors, has hitherto been generally studied as a result of self-induction. The remarkable results which I witnessed in the Mordey machine some years ago led me to examine mathematically the result of there being no self-induction, if this were possible, in practice. If the motor have a less E.M.F. than the generator, and they be in the same phase, work is done on the motor at a rate $= \frac{(E - E')\,E'}{2\,R}$ watts, if E, E' are the E.M.F.'s of generator and motor respectively, and R the resistance of the circuit. If the motor differs in phase, either in advance or retardation, from the generator by an angle a, the work done is at a rate $= \frac{E\,E' \cos a - E'^2}{2\,R}$ watts. Professor Forbes.

Since this work is a maximum when there is no lag, and decreases with the angle of lag, the only stable position is when the motor is in advance of the generator.

If at starting in approximate synchronism a has not the value which makes $\frac{E\,E' \cos a - E'^2}{2\,R}$ = the rate of doing work, there

Professor Forbes.

will be superimposed upon the uniform rotation of the motor an oscillation about the true value for a, until these oscillations are damped out by friction. The period of these oscillations is

$$\frac{1}{2\pi}\sqrt{\frac{M R}{E E' \sin a}},$$

where M is the equivalent mass of the revolving part of the motor at unit radius.

Hence, if R be small, the period is small; and in the Mordey machine it gives a low musical note, which I judged at 16 $\sim$ per second, and which sounded like a deep groan when two alternators were put in parallel with no added resistance, and with initial imperfect synchronism. With a larger value of R the period is longer, and in one case amounted to two seconds to four seconds for the complete period, as judged by me from the pulsations of the "sunbeam" lamps in our Thames Ditton experiment.

I send these notes of what I worked out some years ago, in great haste, and I will probably extend them in another form before long. [*Niagara Falls, N.Y., March* 20, 1894.]

Mr. Mordey says he thinks I was unfair in condemning the Mordey dynamo as unsuitable for our work at Niagara. In answer to his late remarks before the Institution, I will now give reasons in detail for not using his machines.

1. *Hunting with Resistance in Series.*—The account given by Mr. Mordey of our now memorable experiments at Thames Ditton does not accord with my recollections, and Mr. Mordey's present satisfaction with the results contrasts forcibly with his consternation at the time, which I had difficulty in concealing from the Press representatives, and which I took the trouble to do in Mr. Mordey's interest; and for the same reason we did not let them know the object of the experiment, which was for our private information. The experiments just referred to led me to see that certain theoretical results which I had arrived at were correct, and militated against the use of a machine with small self-induction. I have communicated some of these in a hurried note to the Institution a fortnight ago (see above). I will now proceed with others.

2. *Absence of Self-Induction.*—Mr. Mordey has claimed that he has advantages in using a sudden rush of current for synchronising purposes instead of using the lag as explained by Dr. Hopkinson. I consider this most dangerous in practice, and it follows that putting a resistance in the line affects his machine more than others. Professor Forbes.

3. *Effects of Short-Circuiting.*—If a short-circuit on the dynamo occurs, the machine with small self-induction breaks down where others would not do so.

4. *Breakdowns.*—For the information of engineers Mr. Mordey will probably have no objection to publishing the number of breakdowns he has had in the City of London works. A comparison with the performance of the Thomson-Houston plant would also be of interest. I know something of the facts, but it would be more satisfactory to have them from Mr. Mordey's pen.

5. *Absence of Magnetic Leakage.*—Mr. Mordey has claimed that with his arrangement of the north poles all on one side, and the south poles all on the other side, of the armature he is not troubled with magnetic leakage. This is quite incorrect. The magnetic leakage fills up the space between the poles with lines of force, crossing the armature at a point where there ought to be no magnetic field. The performance of the machine depends upon the *difference* of induction at the poles and at the gaps. This machine has its electro-motive force reduced by magnetic leakage more than most machines.

6. *Weight.*—The weight of the revolving part of this type of machine becomes quite unmanageable when we come to the large units necessary at Niagara Falls.

7. *Cost.*—The great advantage usually claimed for the single exciting coil is the reduction in copper used, and consequent cost. In practice this gain is not attained. The Mordey machines do not cost less than others.

I hope Mr. Mordey will consider that I have been sufficiently explicit in giving my reasons for objecting to his method of working, at least in certain cases. For certain purposes it is admirable, and he is aware that I have used many opportunities for saying so.

Professor Forbes. As to the experiments mentioned in his late paper to show that there is no hunting, they go too far, and seem to prove that our eyes misled us at Thames Ditton. The explanation is simple, and is well known to everyone accustomed to work with synchronising alternators. These last results are *selected*. They are the results of experiments with a careful adjustment of the strength of field as regulated by the exciting current. They do not represent everyday practice.

I would like to add an explanation about Fig. 2 in Mr. Mordey's paper, where results are given which are well known. When the field of the motor is highly excited the self-induction is reduced, and the motor leads in accordance with the equations forwarded by me to you a fortnight ago. When the field excitation is reduced, self-induction plays an important part, in accordance with Dr. Hopkinson's equations, and the motor does not lead, but lags. Mr. Steinmetz has worked out these results, and has also shown that a synchronising alternator at the end of a line acts as a capacity and kills the lag due to self-induction.

[*San Francisco, April* 2, 1894.]

Mr. Mordey. Mr. MORDEY, in reply, said: Before entering on my reply to the observations of the various speakers, I wish to correct an impression that my paper was directed entirely to replying to or explaining certain criticisms and objections put forward by Professor Forbes. This was by no means the case. It was only one, and the lesser, of my objects. The paper was intended to be one of general interest on the subject of its title, and Professor Forbes's criticisms were merely taken, as I explained at the outset, as a starting point and text, because they conveniently bring out a number of points which seemed to require clearing up, and on which it appeared to me very little had been said or written. With your permission, I will take the speakers in the order of their speeches, and will be as brief as I can, as there are interesting papers to follow.

My colleague Mr. Raworth, in opening the discussion, was perhaps under the disadvantage of not having read the paper carefully. He probably did not notice that I attributed to the governors exactly the kind of action that he has explained, and

I am glad to have his confirmation of my views on that point. Mr. Mordey.
Either of my explanations is competent to account for the whole thing, but I am inclined to divide it between them. I do not go quite as far of Mr. Raworth in the mechanical explanation.

As to whether governors must necessarily hunt, I, for my part, will stop at the pulley of the dynamos, and leave Mr. Raworth to go further, and to settle with Captain Sankey whether governors must hunt or not.

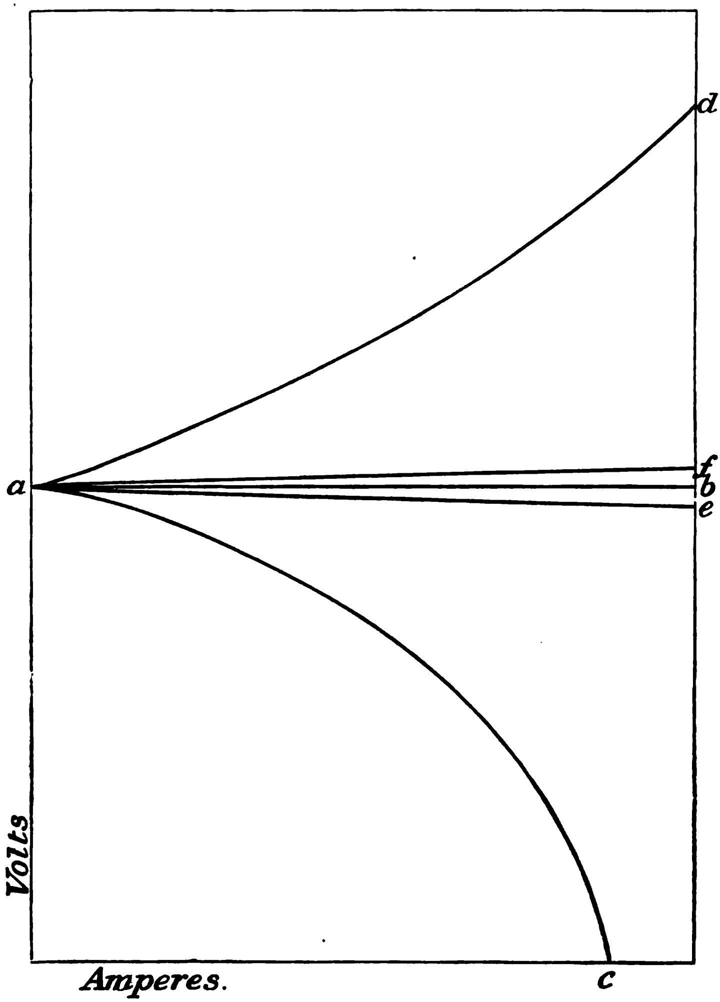
Mr. Sparks followed Mr. Raworth, and emphasised the need for steady turning of the engines driving alternators in parallel work. From Mr. Sparks's experience at Deptford, I was very glad to hear that expression of his opinion. He has there seen a good deal of working with slow engines, even with slow horizontal single-crank engines, the worst type of all that could possibly be used for parallel working; he therefore speaks from rather singular experience.

The next speaker was Mr. Weekes, who supported my view that the change in the resistance of the lamps was contributory to the hunting.

Mr. Kapp spoke at considerable length, and, as usual with him, his observations were of very great interest. Mr. Kapp does not complain of the spur-wheel analogy, but he draws from it conclusions different from my own. I do not agree with him in the conclusion that he arrives at as the result of considering that analogy. In referring to the two types of alternators—to what I compared to the stiff and the flexible spur wheels —he argued in favour of the latter, because he supposed that "the "more it yields, the greater the force it exerts." On this point I am not at one with him. I think that, in reply to something which fell from Professor Thompson, he really supplied the argument against his own view. Professor Thompson supported the view which I had taken in my paper, that the flexible teeth were necessarily weak teeth, and Mr. Kapp interposed with a remark to the effect that the weakness and the tendency to get out of step is prevented by regulating the field excitation. I would point out that that really is the pith of the whole question; it is a question between the amount of regulation and between good regulation

Mr. Mordey. and bad, as I will presently try to explain. A weak-toothed alternator is a machine the field magnetism of which is twisted out of shape and pulled round by reactions, so that the armature and the field take up relatively disadvantageous positions. This must necessarily mean a weakened tooth. But Mr. Kapp in effect says, "Yes, but you can avoid that by adjusting the "field when this weakening is taking place." Unfortunately, you cannot do that. For instance, under the circumstances that I mentioned and dealt with, I am afraid at considerable length (in trying to make these analogies clear), I pointed out that, whilst one engine is going over the dead centre and slowing, while another engine is taking steam and accelerating a little, there is a difference in speed between them, or a tendency to difference in speed, which must be counteracted by very rapid interchange of power between the two machines. This means that at each stroke of the engine, or perhaps twice in each stroke, or oftener (according to the number and setting of the cranks), there is an interchange of power taking place. Now, of course, it will be acknowledged that no one can possibly regulate for that. This is one reason why I argue in favour of machines being designed which do not require this regulation,—not merely because they give a constant, or nearly constant, strength, a constant synchronising effort, but (what follows from their having that quality) because they comply with what ought to be one of the principal conditions necessary to the good working of central stations—I mean that they have nearly a constant E.M.F. Perhaps I may be allowed to use a diagram to explain my meaning. Let us take the curves connecting E.M.F. and current in the two types of alternators. Horizontal values represent load, vertical values represent E.M.F. Then a perfect machine for parallel working for alternate-current distribution, as well as for the purposes of a good and even supply, would be one that gave a perfectly straight line, *a b*. No machine gives such a result, but I suppose all designers attempt to approach it. In order to correct any departures from it, the excitation has to be regulated either by hand or by some method of automatic regulation or compounding. That is to say, in order to get that straight line

with any machines, you have to increase the excitation of the field as the load goes on. You may have to increase it a Mr Mordey.



great deal or only a very little. Take the two cases. First take the type of alternator with yielding teeth. Let the excitation be such as gives full E.M.F. with no load. Do not increase the excitation at all, and put the whole load on, either gradually or all at once, and the E.M.F. will fall, giving you a curve something like *a c*. This drooping curve may be such

Mr. Mordey. (and you may be surprised to hear that I speak from experience of modern machines made by people of good reputation) that the machine will actually not give its full current, even with no terminal volts (that is, on short-circuit), with that minimum excitation. Suppose that you then began to raise the excitation so as to get the volts up again to *b*. We will suppose that, having in this way got full current *and* full volts, you then switch the load off; or (what may happen at any time) we will suppose that the fuses give way for some reason or other. You have no possible opportunity of regulating the fields: it is an instantaneous matter, and the machine has to take its chance. The terminal volts have gone up from *b* to *d*.

Now consider the type of machine with strong or unyielding teeth; and I may be allowed to refer to 500-kilowatt machines of my own design, as I can give actual figures. The variation of volts was about 4 per cent. either way. That is, with the excitation fixed, the drop was from *a c* to *a e* when the whole load was suddenly thrown on; the rise was from *a c* to *a f* when the whole load was suddenly switched off. That is to say, suppose the engine to be running at constant speed, you could put the whole load on or take it off, as you like, and you would only have the variation of E.M.F. that is shown between *e* and *f*. Not only is the amount of hand or automatic regulation that is necessary to maintain a constant E.M.F. very small, but the variation in voltage, with changes of load, is comparatively unimportant.

Now imagine machines of these types running parallel with engines that are unsteady in speed; the governors are sticking or hunting, or the driving may be normal but uneven. The alternators are giving corresponding pulsations; the current is varying. What happens to the machine which has yielding teeth or a drooping curve? Its E.M.F. is alternating between nothing (that is, the point *c*) whenever it tries to take a large current, and the point *d* whenever by reason of its momentary retardation, or because of its not having steam, the load is transferred to the other machine. These enormous variations of E.M.F. cannot, of course, be controlled, and great unevenness of

working is unavoidable. In the case of the other machine, the variation of volts is only from e to f instead of from c to d. And it will be observed that these variations in either case take place with single machines working on circuits which are subject to variation. So that it is not merely in the parallel working qualities of the machine that this point is of importance. It is of very great importance, because it affects practical qualities for the purposes of an even supply. The kind of complaint that one has to face—and engineers of electricity stations will confirm what I say—is simply that of variation of E.M.F. The variation of E.M.F. is much more difficult to avoid in machines of one type than in machines of the other. Of course there is no side which is so good that the other side is all ill; but these are some of the considerations which, in my view, govern the qualities that should be aimed at in apparatus of this kind. This quality of good regulation is what you must arrive at some day, and in my opinion it is what should be made the starting-point. It is quite possible to make machines which have all the other good qualities without having to fall back on what I call the Niagara type of curve. Mr. Mordey.

Mr. Kapp made some interesting remarks about the "V" curves; but I am quite unable to agree with him that, in order to give a synchronous motor a suitable margin, it should be excited to the same E.M.F., or preferably higher than the generator. My tests E, F, and G, and the reasoning from them, seem to me to point to an opposite conclusion—namely, that the motor will most readily do its work and keep in step, and with the smallest current, when its E.M.F. is slightly lower than the E.M.F. impressed on it from its source of supply. If its E.M.F. is higher it can only receive current by slightly departing from the most advantageous phase relation.

Professor Thompson followed Mr. Kapp. I need not further refer to what passed between him and Mr. Kapp on the conclusions to be drawn from my analogies.

The subject of governors and of a common steam supply, as introduced by Professor Thompson, is, in my view, a very important one, but in answer to his question I am not able

Mr. Mordey. to refer him to any case of the use of such a common supply; but I would like to be allowed to recall attention to some remarks of mine on the subject in a previous volume of the *Journal*,* in which I pointed out that when two or more machines are working together parallel they are practically one machine, and necessarily driven at one speed. It is, therefore, on the face of it wrong, although it may be convenient for practical reasons, to have them governed individually by speed governors. The speed governors, of course, cannot govern at all if the speed remain constant, as it is supposed to do. Under these circumstances individual governing by speed governors is unsatisfactory. If the governors were all exactly alike in range and sensitiveness, all the machines would rise and fall in speed together within the limits of the governing range, and with properly proportioned power. In practice they keep together by a sort of perpetual give-and-take arrangement which leaves much to be desired. Therefore I pointed out that, at any rate theoretically, the right way appears to be to let all the engines run without governors, to run on a common steam supply, and to let the steam supply be governed by one governor (driven mechanically or electrically in connection with the engines or alternators), or by hand, and in such a way as to keep the speed constant for the varying loads. I daresay engineers will have objections to raise on the score of efficiency of steam consumption to that proposal, but as far as it goes it seems to be sound enough. And I pointed out that if there are any governors on the individual engines they should be dynamometric governors, and not speed governors; and that the speed governors should be used merely for the purpose of preventing injury in case of disconnection or fuses going, or any injurious racing. A very good safety governor of this kind is the thing used in the North country, and which is, I believe, called an electric engine-stopper. It lets steam into a little auxiliary cylinder, which turns off steam at the stop valve.

General Webber has asked me a question that I am not able to reply to as to the working of the plant at the Wool Quay

* *Journal*, xxii., p. 193.

sub-station and at Bankside. I never was at Wool Quay in my life. Mr. Mordey.

I have to thank Captain Sankey for recalling to my mind the fact that at Thames Ditton we did not get the machines out of step until we had pulled the speed down from about 600 to 25 revolutions per minute. I did not quite understand him as to the difference between the time-period of a governor and the hunting of a governor, but I am sure his remarks on this and on the indicator card will be of great interest when printed. I do not quite think that the hunting could have been due to change of load in the experiments that were made in 1891, because there was no load. I am glad to have the information also as to the resistance of the lamp, and to note that the change of resistance between the incandescent state and the cold state was even greater than I supposed. That goes a long way to support the contention I raised that this very marked change in the resistance of the circuit between the machines had a great deal to do with the hunting. Captain Sankey's kind offer to afford opportunities for further testing would have been accepted with pleasure if I did not feel that the subject had already been pretty fully thrashed out.

Professor Ayrton's idea as to static synchronisers has occurred to others, as he expected would be the case. It occurred to me some two years ago, I think, and I made some rough experiments on pith-ball and gold-leaf electroscopes, and other forms, which, although not carried very far, showed that static instruments could be used quite well as phase indicators. I did not pursue the matter, because for engine-room purposes it is necessary to have a very clear signal for the engine-driver, who is away, perhaps, a considerable distance from the switch-board or synchroniser, and it is necessary that he should be able to see quite clearly what is going on, and so to adjust the speed to give satisfactory synchronism. For this reason a lamp seems a necessity, and for this purpose it is best to use the usual double transformer. And, besides the lamp, a sensitive instrument, in addition, is an advantage for the guidance of the person working the switch; an ordinary voltmeter is readily put in parallel with

Mr Mordey. the lamp. Thus both electrician and engine-driver are provided for. Otherwise, I think a static device would work perfectly well.

The short communication sent by Professor Forbes, dated Niagara, March 20th, although evidently not intended to deal with any special point in my paper, strikes me as singularly apposite to the general question of synchronous running. For four years past I have maintained that the practical solution of this problem is something different from that deduced by Dr. Hopkinson from his differential equations. That is to say, without disputing the correctness of his deduction, which made self-induction the controlling factor in the operation, I have argued, upon the basis of experience, that the best and most perfect synchronising was to be obtained by using such arrangements as would give the readiest interchange of current between the leading and the lagging machines; leading necessarily to the view that the absence rather than the presence of self-induction was to be desired. Professor Forbes, by eliminating from the equations which he now sends the expression for self-induction, shows what then are the conditions favourable for the maintenance of synchronism. The result is that he has adopted (without acknowledgment), and has thrown into mathematical form, the principle at which I had arrived, and which I brought before this Institution four years ago, as a result of experience, on which occasion he was present. Now that my views have received the consecration of x's and y's, I may dare to hope they will be honoured with the tardy approval of those critics who have hitherto failed to be convinced by the logic of facts expressed in the vulgar tongue.

Professor Forbes has sent a further contribution to the discussion, dated San Francisco, April 2nd, and it would have given me great pleasure to reply to it point by point but for the fact that my paper already deals with most of the issues raised. His remarks, for the most part, amount simply to statements which show that our views are not in agreement; but, as I cannot hope to convert Professor Forbes, we must agree to differ.

A few new points arise, however, out of his communication, and to these I will briefly refer.

1. In view of my previous satisfactory trials (Test A, p. 266), Mr. Mordey.
I had expected the machines either to go out of step or to stay in, and I was therefore a little puzzled at first by the hunting; but to learn now that my attitude was one of "consternation" is certainly a surprise to me. I quickly arrived at an explanation of the affair, and supposed Professor Forbes had done the same, since from that day till the present occasion he never alluded to it.

The "theoretical results" I have already alluded to.

2. With reference to this section, I wish to point out that Professor Forbes's statement is deserving of respect as an expression of his opinion, but it is not a statement of fact. He says that my machine is more affected than others by having resistance put in the line, and considers that, instead of using a current for synchronising purposes, I ought to use a lag. So far as I can put an interpretation on these words, they mean (put in a practical form) that, if I were working a synchronous motor on a line of such high resistance that it would not keep in step, I should enable it to keep in step by adding self-induction to the circuit—say by putting a choking coil in the circuit. I have not tried this experiment, but believe it would have exactly the opposite effect to that expected by Professor Forbes.

This, however, can be of only theoretical interest, seeing that a number of experiments have demonstrated that the machines will work through at least 30 times any possible reasonable line resistance. Professor Forbes asserts that other machines are less affected by resistance than this, but he supports this assertion by no shred of evidence.

3. I have always maintained that a machine that could be kept running with a short-circuit in it was lacking in every other good quality. Its reactions are so enormous that its bad regulating qualities render it very difficult and objectionable to use.

4. On this point I would only say that the comparison asked for would fully justify all I have claimed.

5. What I have claimed is strictly true. The leakage between adjoining poles is *nil*. Professor Forbes fails to grasp the significance of this.

6. This objection is one that need not cause much difficulty.

Mr. Mordey. The weight could be reduced far below that now being used at Niagara, as Professor Forbes is quite aware.

7. On this point Professor Forbes has no information. Our costs have never been published.

On the last paragraph I would only remark that Professor Forbes misreads Fig. 2. It was not intended to illustrate self-induction at all, but relative E.M.F. of generator and motor.

I am very glad that Professor Forbes has been able to send these two communications. It was a matter of regret to me that his continued absence prevented our having him at the Institution when my paper was read.

I have to express my thanks for the reception of the paper.

The President. The PRESIDENT: I need not ask you to thank Mr. Mordey again, but I would like to say a few words with regard to a remark made by Mr. Raworth in the discussion. You will recollect he said that at our works 14 years ago an attempt was made to run machines in parallel with 70 ohms resistance between the machines. I have looked the matter up, and find that we tried in 1884 to work an alternate-current machine as a motor through 70 ohms resistance, and we were perfectly successful. It was with a view of transmitting the power to a distance by means of alternating currents that we made the experiments, and shortly afterwards we also succeeded in running the old form of the Siemens alternators in parallel. Of course the experiments were carried further; but I need not go further into the matter, as you will have seen by what I have said that Mr. Raworth's recollection was not quite accurate.

I will now call upon Professor Ayrton to read the next paper.

A UNIVERSAL SHUNT BOX FOR GALVANOMETERS.

By W. E. AYRTON, F.R.S., Past-President,

and

T. MATHER, Associate.

Professor Ayrton and Mr. Mather. Several years ago Mr. Latimer Clark drew attention to the fact that when shunts were used with a ballistic galvanometer in

the comparison of the capacities of condensers, the results were inaccurate if the multiplying powers of the shunts were assumed to be the same as those employed with steady currents; shortly afterwards the matter was investigated mathematically by the late Mr. Hockin, and he showed that the inaccuracy was caused by the change which the application of the shunt produced in the damping of the swing of the ballistic galvanometer. Hence the instantaneous deflection of a galvanometer when shunted showed an extra diminution, as if its resistance had been increased by the amount which depended on the details of the construction of the particular galvanometer, and on the adjustment of the controlling magnet.

Professor Ayrton and Mr. Mather.

In 1892, when giving a preliminary account of our "workshop "ballistic galvanometers" at the Physical Society, we incidentally mentioned a method that we had devised of constructing shunts which entirely overcame this difficulty. At that time we had only perceived that our method of constructing *constant-damping* shunts was of value in connection with ballistic galvanometers; but subsequently it occurred to us, when specifying the resistance of such constant-damping shunts, that this method of construction not only removed the difficulty which had been pointed out by Mr. Latimer Clark in connection with ballistic galvanometers, but it enabled the same shunt box to be used with any number of different galvanometers of any resistance and of any type, and with an accuracy in the measurement far greater than could be obtained with the ordinary form of shunt box which had been specially constructed for the particular galvanometer.

As this method of making shunt boxes has not yet been published, and as it possesses important advantages of which we were not aware when we alluded to it at the Physical Society, we have thought that a short description of the method may interest the members of the Institution of Electrical Engineers.

To appreciate its advantages let us first consider the common, well-known method of constructing shunts, and the defects it possesses.

1. The resistances of the 1-10th, 1-100th, and 1-1,000th shunt must have exactly 1-9th, 1-99th, and 1-999th of the

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resistance of the galvanometer; therefore, if the resistance of the galvanometer be 1,000 ohms, for example, the shunts must have 111·1, 10·10, and 1·001 ohms resistance; hence we must construct the 1-1,000th shunt accurately to the one-thousandth of an ohm if we wish it to be correct to even 1-10th per cent.

2. But the galvanometer is wound with copper wire: we are therefore at once met with the difficulty as to what wire we ought to employ in winding the shunts. If we use German silver, platinoid, manganin, or any substance of low temperature coefficient for the wires of the shunt coils, their resistances may be quite constant, but a rise of 10° C. in the temperature of both the shunts and of the galvanometer will make an error of 4 per cent. in the resistance of the former relatively to that of the latter.

If, on the other hand, we wind the shunts with copper wire, then, since the shunts are not inside the galvanometer case, it is very difficult to ensure, from the readings of thermometers, that there is not a difference of some two or three degrees between the mean temperatures of the shunt box and of the galvanometer, so that the resistances of the shunts may easily be 1 per cent. wrong relatively to that of the galvanometer.

In fact, except in the rare case when the galvanometer as well as the shunts are wound with German silver, manganin, or other wire of low temperature coefficient, it is useless spending time making accurate adjustments of the resistances of the shunt coils as ordinarily constructed.

3. Even if the resistances of the shunts be exactly 1-9th, 1-99th, and 1-999th of the galvanometer, they act as if they did not allow 1-10th, 1-100th, and 1-1,000th respectively of the charge in a condenser to pass through the galvanometer when used ballistically.

4. Lastly, for each galvanometer there is needed a separate set of shunts.

All these defects arise from the fact that the method hitherto adopted of varying the current through a galvanometer while the current in the main circuit remained the same, has consisted in varying the resistance of the shunt to the galvanometer. If, however, we leave the shunt to the galvanometer untouched, and, instead, vary the current through the galvanometer by varying the point of attachment of the main leads, we remove all these difficulties at once. Professor Ayrton and Mr. Mather.

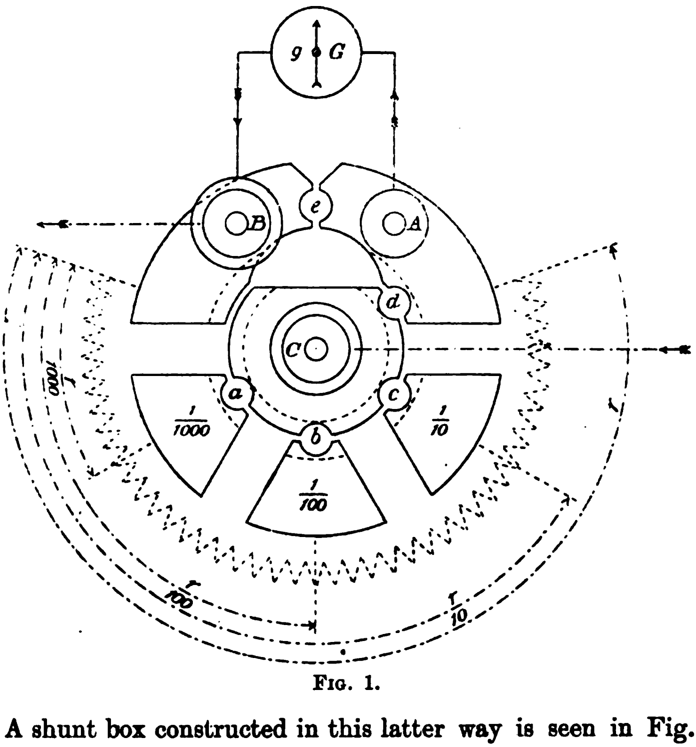

FIG. 1.

A shunt box constructed in this latter way is seen in Fig. 1. The terminals A and B of the shunt box are permanently connected respectively with the terminals of the galvanometer G, while the terminals B and C of the box are connected with the two main wires which lead the current up to, and away from, the galvanometer and shunt. The ends of a coil of *any* resistance r ohms are permanently connected as shown, and at points in this coil corresponding with $\frac{r}{10}, \frac{r}{100}, \frac{r}{1,000}$ ohms permanent

Professor Ayrton and Mr. Mather.

connections are made with the various blocks of the shunt box as illustrated.

Then, whatever be the resistance of this coil, r, compared with the resistance of the galvanometer g (either, or both, of which may therefore be unknown), it is easy to show that if G amperes be the current flowing round the galvanometer when a plug is placed into the hole marked d, it will be $\frac{G}{10}$, $\frac{G}{100}$, and $\frac{G}{1,000}$ amperes respectively when the plug is put instead into the holes marked c, b, and a respectively provided that the current in the main circuit remains constant—the condition which is, of course, assumed to be true in the ordinary use of shunts. Or, if a definite quantity of electricity flow into or out of a condenser in the main circuit, and Q coulombs be the quantity of electricity that flows round the galvanometer when the plug is in the hole marked d, $\frac{Q}{10}$, $\frac{Q}{100}$, and $\frac{Q}{1,000}$ coulombs will be quantities that flow round the galvanometer when the plug is put into the holes c, b, and a respectively, and the deflections will correspond with these quantities.

For let the constant current in the main circuit be called A: then, when plug is in hole d, the galvanometer current equals

$$\frac{r}{r+g}A, \text{ say } G;$$

when plug is in hole c, the galvanometer current equals

$$\frac{\frac{r}{10}}{\frac{r}{10}+\left(\frac{9}{10}r+g\right)}A, \text{ or } \frac{G}{10};$$

when plug is in hole b, the galvanometer current equals

$$\frac{\frac{r}{100}}{\frac{r}{100}+\left(\frac{99}{100}r+g\right)}A, \text{ or } \frac{G}{100};$$

when plug is in hole a, the galvanometer current equals

$$\frac{\frac{r}{1,000}}{\frac{r}{1,000}+\left(\frac{999}{1,000}r+g\right)}A, \text{ or } \frac{G}{1,000}.$$

Similarly, if K be the number of coulombs flowing into, or out of, a condenser in the main circuit, and pK, or Q, be the number of coulombs that flow round the galvanometer when the plug is put into the hole marked d, it may be proved that, *since the resistance of the galvanometer plus that of the shunt is constant, and therefore the damping is constant,* the quantities of electricity that will flow round the galvanometer when the plug is put instead into the holes marked c, b, a, respectively, are $\frac{Q}{10}$, $\frac{Q}{100}$, $\frac{Q}{1,000}$ coulombs. Professor Ayrton and Mr. Mather.

Hence the galvanometer may be wound with copper or with any other wire; a single set of shunts may be made of manganin wire, and be accurately subdivided into *exact* numbers of ohms, *fractions of an ohm being unnecessary with our system;* the galvanometer may have any resistance and be at any temperature, provided it is constant while a set of tests is being made,—then the subdivision of a steady current or the subdivision of an instantaneous rush of electricity into parts having the ratios of 1, $\frac{1}{10}$, $\frac{1}{100}$, $\frac{1}{1,000}$, is effected with *great accuracy.*

Stock shunt boxes, ready wound for use with any galvanometer, in the measurement of steady currents or of instantaneous rushes of electricity, are exhibited on the table.

The arrangement of shunt box illustrated in Fig. 1 may be regarded as possessing one defect—viz., that the whole current flowing in the mains cannot be sent round the galvanometer without disconnecting the main wire from the terminal C, and connecting it instead with the terminal A. To save the trouble of having to do this, and to enable every combination to be made by simply shifting the plugs, we sometimes construct the blocks of the shunt box as seen in Fig. 2. When one plug is placed and left in the hole marked h, and a second plug is placed in one or other of the holes marked d, c, b, or a, we obtain exactly the results already described in connection with the box seen in Fig. 1. Placing, however, one plug only in the hole marked f, the entire current flowing in the mains circulates round the

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galvanometer. If a plug be placed in the hole *f*, and another in the hole *j*, the galvanometer is short-circuited—a result obtained

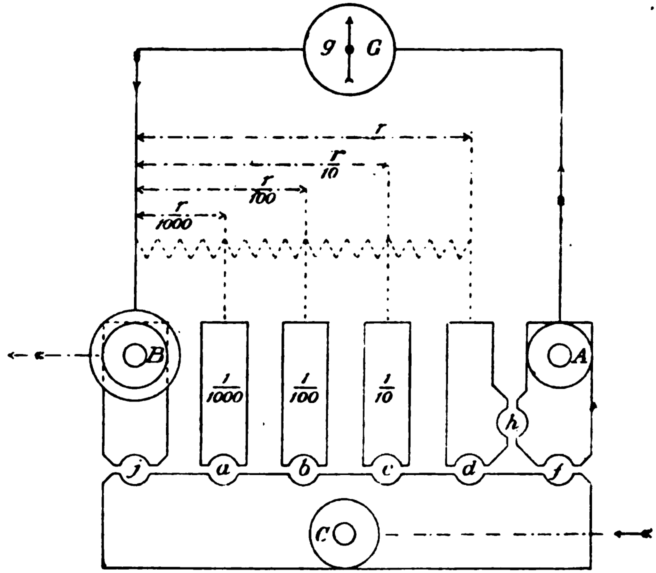

Fig. 2.

by placing the two plugs in the holes marked *d* and *e* in Fig. 1. The arrangement shown in Fig. 2 has the further advantage that it is possible, by putting a single plug into the hole marked *j*, to disconnect one terminal of the galvanometer from the circuit without breaking the circuit. This method of connecting is convenient to employ when taking the zero with a very sensitive galvanometer, for in that case it may happen that, although the galvanometer is apparently short-circuited through a very low resistance, enough of the main current, although but an extremely small fraction, passes round the galvanometer to produce a small deflection.

When, however, r is more than about ten times as great as g, the simpler form of shunt box illustrated in Fig. 1 is sufficient for ordinary purposes; for, although by merely shifting the plug with this type of box it is impossible to send a greater current round the galvanometer than $\frac{r}{r+g}A$ amperes, where A is the

current in the mains, this value of G, being more than $\frac{10}{11}A$, is sufficiently near A for ordinary purposes. Professor Ayrton and Mr. Mather.

Of course, whatever be the value of r, whether large or small compared with that of g, the current that flows round the galvanometer when the plug is put into the poles marked c, b, and a respectively, is exactly 1-10th, 1-100th, and 1-1,000th of its value when put into the hole marked d. The only advantage that is gained by making r large compared with g is that $\frac{r}{r+g}A$, or G, the unit current, becomes then practically equal to A.

The method of using shunts above described has, then, the advantage that it enables the same shunt box to be used with any galvanometer of any resistance, whether ballistic or not; but it does more than that, for a consideration of our method of varying the point of attachment of one of the mains, instead of varying the resistance of the shunt itself, shows that *any ordinary* resistance box can be employed as a shunt with *any* galvanometer, and the fractions of the current that pass round the galvanometer and through the shunt respectively can be read off at once, *without any calculation and without a knowledge of the resistance of the galvanometer*, to a far higher degree of accuracy than is possible with a set of shunts specially constructed for the particular galvanometer in the ordinary way.

By employing this device we also find that great simplification and cheapening of cost is effected in the employment of a d'Arsonval galvanometer with shunts of platinoid or manganin sheet for the measurement of electric currents over a wide range.

It is well known that with the ordinary method of constructing shunts the resistance of the circuit is altered when the shunt is varied. An interesting question therefore arises whether this change in the resistance of the circuit is greater with the method that we have proposed of constructing a shunt, or with the ordinary method.

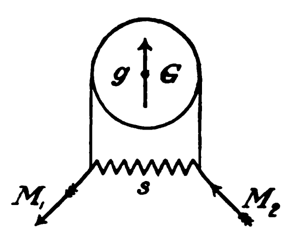

FIG. 3.

Professor Ayrton and Mr. Mather.

With the ordinary method of keeping the main leads, M_1, M_2 (Fig. 3), permanently connected with the galvanometer G, and of varying the current through the galvanometer by altering the resistance, s, of the shunt, the change that is produced in the resistance of the circuit on applying this shunt is, as well known, from g to $\frac{s\,g}{s+g}$; that is, the resistance is diminished by $\frac{g^2}{s+g}$. If, then, the shunt be such as to allow $\frac{1}{n}$th of the current to pass through the galvanometer, s equals $\frac{g}{n-1}$, and the resistance in circuit is diminished by $\frac{n-1}{n}g$ when this shunt is applied. For example, if n be 10, the resistance of the circuit will be diminished by 9-10ths of g.

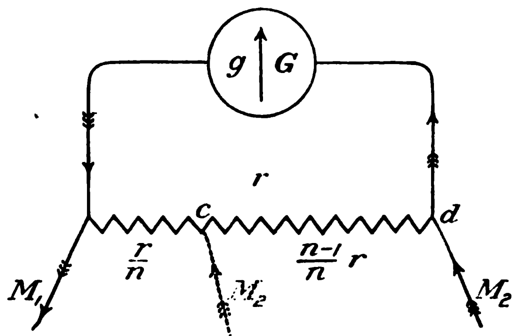

FIG. 4.

With our proposed method of keeping a *fixed* resistance, r, attached to the galvanometer G (Fig. 4), and of varying the current through the galvanometer by varying the connection of one of the main wires—for example, by moving the main wire M_2 from the point d to the point c—the resistance of the circuit is altered *from* $\frac{r\,g}{r+g}$ to $\frac{\frac{r}{n}\left(\frac{n-1}{n}r+g\right)}{r+g}$; that is, the resistance in the circuit is diminished *by*

$$\frac{1}{r+g}\left\{\frac{n-1}{n}r\,g-\frac{n-1}{n^2}r^2\right\} \quad \ldots \quad \ldots \quad (1)$$

Now this expression depends not merely on the values of n

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and g, but also on the value of r. If r is selected so as to be less than $n\,g$, the expression (1) is positive—that is, the resistance of the circuit is *lessened* by shifting the main M_2 from the point d to the point, c; whereas, if r is selected so as to be greater than $n\,g$, the expression (1) is negative, which means that shifting the main M_2 *increases* the resistance of the circuit. Lastly, if r be chosen so as to be exactly equal to $n\,g$, shifting the main produces *no change whatever* in the resistance of the circuit; so that the current *now* passing through the galvanometer after shifting M_2 is exactly $\frac{1}{n}$th of the current that *previously* passed through the galvanometer, for the current in the main circuit undergoes no change whether the resistance of the circuit be large or small.

By selecting r, then, so that it is roughly equal to $n\,g$, our proposed arrangement gives the following result on shifting the main M_2 from d to c:—

(*a.*) If the resistance of the rest of the circuit be large compared with that of the galvanometer, the current that *now* passes through the galvanometer is exactly $\frac{1}{n}$th of that which *previously* passed, whatever be the temperature.

(*b.*) If the resistance of the rest of the circuit be even small compared with that of the galvanometer, the current that *now* passes through the galvanometer is very nearly $\frac{1}{n}$th of that which *previously* passed, whatever be the temperature.

Contrasted with this, we have, with the ordinary method of applying a shunt, the result:—

(*a.*) Even if the resistance of the rest of the circuit be large compared with that of the galvanometer, it is only when the temperature has one definite value that the current that *now* passes through the galvanometer is exactly $\frac{1}{n}$th of the current that *previously* passed.

(*b.*) If the resistance of the rest of the circuit be small compared with that of the galvanometer, the current that *now*

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passes through the galvanometer is far greater than $\frac{1}{n}$th of the current that *previously* passed.

Lastly, whatever be the values of g, r, and n, provided that r be less than $g\,(n + \sqrt{n^2 + n})$, our method of altering the current through the galvanometer produces less change in the resistance of the circuit from its original value than the ordinary method. For, as already seen, with the ordinary method of applying a shunt the resistance of the circuit is diminished by $\frac{n-1}{n}\,g$; while on moving the main M_2 from d to c with our method the resistance of the circuit is diminished by

$$\frac{1}{r+g}\left(\frac{n-1}{n}\,r\,g - \frac{n-1}{n^2}\,r^2\right);$$

therefore the change in the resistance of the circuit when using our shunt box is to the change with the ordinary shunt box as

$$\frac{1}{r+g}\left(\frac{n-1}{n}\,r\,g - \frac{n-1}{n^2}\,r^2\right) \text{ is to } \frac{n-1}{n}\,g.$$

Consequently the ratio of the alterations produced in the resistance of the circuit by the use of the two shunt boxes respectively equals

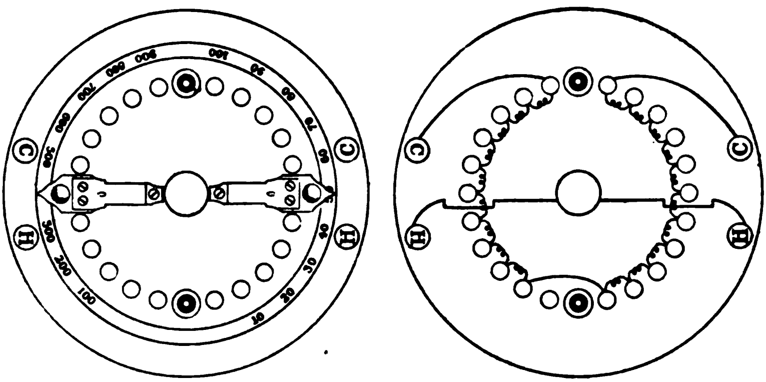
$$\frac{1}{r+g}\left(\frac{r^2}{n\,g} - r\right),$$

which will be numerically less than unity when

$$r \text{ does not exceed } g\,(n + \sqrt{n^2 + n}) \quad \ldots \quad (2)$$

From the result (2) it follows that, if r be not more than 20·488 times the resistance of the galvanometer, the change in the resistance of the circuit, from its original value, produced by using the 1-10th, 1-100th, and 1-1,000th shunt, will be *less* with a universal shunt box than with the ordinary shunt box. So that, if the resistance of no one of a set of galvanometers be less than 1,000 ohms, the universal shunt box may have a total resistance of 20,488 ohms, and still this additional advantage will be gained when using *each* of the galvanometers. Or, if the resistance of the universal shunt box be 10,000 ohms, this additional advantage will be gained with any galvanometer of high or low resistance, provided that the galvanometer resistance be not less than 488 ohms.

Mr. F. HIGGINS [*communicated*]: I have to-day received a proof of the paper by Messrs. Ayrton and Mather on "A Universal "Shunt for Galvanometers." Subjoined is a drawing of a convenient form of apparatus which I have used in exactly the same Mr. Higgins



manner and for the same purpose for more than 20 years past. The two hands connected to the terminals marked H are insulated from one another, and can be connected by 1-100ths to any part of the wire, of 1,000 ohms resistance, terminating at C C. By this means, and the variation of the resistance in the battery circuit, measurements may be taken with any desired potential, or, conversely, any potential may be balanced, and thus measured against a standard.

Mr. CROMPTON: It appears to me that, after all, a further extension of the method of shunting proposed by Professor Ayrton is the potentiometer method which I have so often advocated; for the graduated wire of a potentiometer is practically a shunt to the galvanometer, and the sliding contact is a convenient method of changing the value of this shunt. Of course I mean that this slide wire should be used potentiometer fashion; that is to say, that instead of being a shunt of high resistance, it takes the form of a wire of low resistance, carrying a constant E.M.F. opposed to the E.M.F. that is being used for testing. Mr. Crompton.

Professor AYRTON: I will answer the questions in inverse order. With reference to the graduated wire suggested by Mr. Professor Ayrton.

Professor Ayrton.

Crompton, of course that would not do at all when you are dealing with a high-resistance galvanometer, for it is desirable that the greater part of the current coming along the mains should flow through the galvanometer, and that would not be the case unless the graduated wire had a resistance large compared with that of the galvanometer itself. In one sense, of course, every resistance box is a graduated wire, and therefore in one sense you may say that whenever you use a resistance box you use a graduated wire; but it is not a graduated wire in the ordinary sense of the word.

It is a great pity, if Mr. Higgins has for 20 years been aware of the fundamental principle underlying our Universal Shunt Box, that he has not given the world the benefit of his knowledge. Why, on the occasion when Mr. Latimer Clark made his communication to this Society, and Mr. Hockin published his mathematical investigation in connection with the matter, did not Mr. Higgins say, "Here is a method which gets over all your "difficulty, Mr. Latimer Clark, and renders the mathematics of "Mr. Hockin unnecessary"? By doing this he would have conferred a great benefit on electricians, because certainly they did not see, until we suggested the method at the Physical Society, how you could construct a system of shunts so that for ballistic purposes the multiplying powers would always have the same values, viz., those they possessed for direct-current measurements. And certainly they have not seen—I think it is the best answer—that it was possible to make stock shunt boxes suitable for any galvanometer, whether used ballistically or not; if they have, then why did they not construct them for sale? Of course, now that we know how to solve the problem, the solution appears so absurdly simple that you feel certain everybody must have known it; still, not only have we never seen *stock* shunt boxes constructed before, but we have never seen even the principle of our method suggested in any book or technical publication.

The following paper was then read:—

THE BEST RESISTANCE FOR THE RECEIVING INSTRUMENT ON A LEAKY TELEGRAPH LINE.

By Professor W. E. Ayrton, F.R.S., Past-President,
and
C. S. Whitehead, M.A.

1. If there be a single earth fault at any one point of an otherwise good telegraph line, $P\,Q$ (Fig. 1), it is easy to prove Professor Ayrton and Mr. Whitehead.

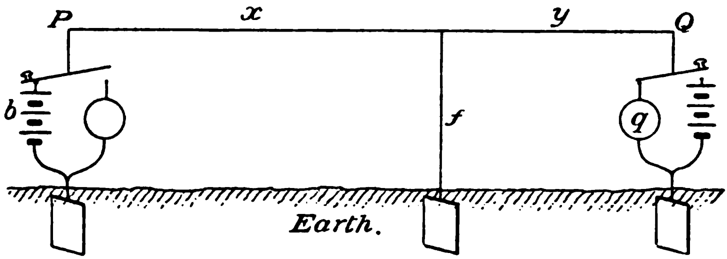


Fig. 1.

that the best resistance to give to the receiving instrument at either end of the line is equal to the apparent resistance of the line tested from *that* end when put to earth at the other end through a resistance equal to that of the signalling battery at that end. For example, if we desire to know what should be the value of q, the resistance of the receiving instrument at the Q end, the line must be tested from the Q end (Fig 2) when put

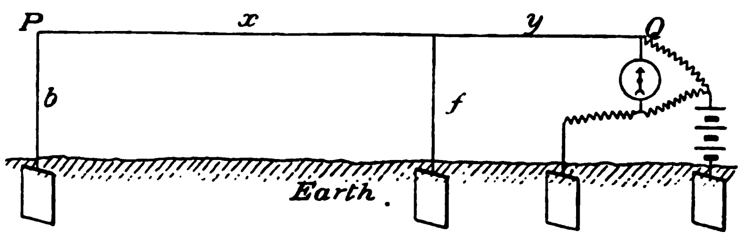


Fig. 2.

to earth at the P end through a resistance, b, equal to that of the signalling battery usually employed at that end.

For if E be the E.M.F. of the signalling battery at the P end,

Professor Ayrton and Mr. Whitehead.

f the resistance of the single earth fault, and x and y the resistances of the two portions of the line, the current, A, that flows through the receiving instrument at Q (Fig. 1) equals

$$\frac{f}{f+y+q} \times \frac{E}{b+x+\frac{f\,(y+q)}{f+y+q}}.$$

And the magnetic effect produced by an electro-magnet of given size, shape, and construction is proportional to the product of the current into the square root of the resistance of the wire with which the coil is wound. Therefore it follows that the magnetic effect of the receiving instrument at Q is proportional to $A\sqrt{q}$, that is, to

$$\frac{f\,E\sqrt{q}}{(f+y+q)\,(b+x)+f\,(y+q)};$$

and this has a maximum when

$$q = y + \frac{f\,(x+b)}{f+x+b},$$

that is, when q is equal to the apparent resistance of the line tested from the Q end and put to earth at the P end through a resistance b.

2. During the course of some lectures at the Guilds Central Technical College last year on faults on telegraph lines, the question arose whether the above result was universally true for a distributed leak all along the line, or only for a single earth fault; and, if this solution were not generally true, then what was the best resistance to give to the receiving instrument at the end of a telegraph line the leakage along which followed any law. The following is the complete solution of this question:—

Let x be the resistance of the line up to any point measured from the sending or signalling end, P, and let $F\,(x)$ be the insulation resistance of a length of wire at that point having one ohm conductor resistance. When a signal is sent, let V be the P.D. set up between the line and the earth at the sending end (Fig. 3), and v the potential of the line at any point x: then v is given by the equation,

$$\frac{d^2 v}{d\,x^2} = \frac{v}{F\,(x)} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

If $F\,(x)$ be some simple known function of x, it may be

possible to integrate this equation, and in that case we may proceed by performing the integration. For example, if $F(x)$ be Professor Ayrton and Mr. Whitehead.

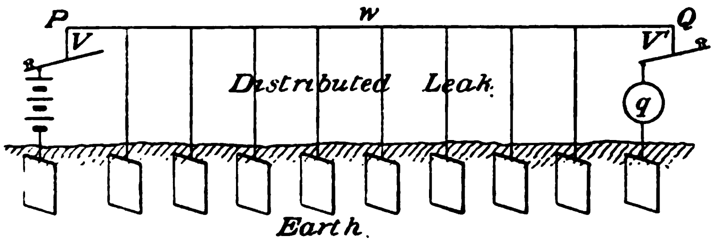


FIG. 3.

a constant, t—that is, if the line be uniformly leaky—then, integrating, and introducing the terminal conditions, it may be shown that

$$v = V \frac{(\sqrt{t} - q)\, \epsilon^{\frac{x-w}{\sqrt{t}}} - (\sqrt{t} + q)\, \epsilon^{\frac{w-x}{\sqrt{t}}}}{(\sqrt{t} - q)\, \epsilon^{-\frac{w}{\sqrt{t}}} - (\sqrt{t} + q)\, \epsilon^{\frac{w}{\sqrt{t}}}} \qquad (2)$$

where w is the true wire resistance of the whole line, and q is the resistance of the receiving instrument at the far end, Q.

Hence the current passing through this receiving instrument, which is $-\frac{d\,v}{d\,x}$ when x equals w, has the value,

$$\frac{2\,V}{(\sqrt{t} + q)\, \epsilon^{\frac{w}{\sqrt{t}}} - (\sqrt{t} - q)\, \epsilon^{-\frac{w}{\sqrt{t}}}};$$

and the magnetic effect, M, is proportional to this expression multiplied into $\sqrt{q}$. From this it may be shown that M is a maximum when

$$q = \sqrt{t}\, \frac{\epsilon^{\frac{w}{\sqrt{t}}} - \epsilon^{-\frac{w}{\sqrt{t}}}}{\epsilon^{\frac{w}{\sqrt{t}}} + \epsilon^{-\frac{w}{\sqrt{t}}}} \quad \dots \quad \dots \quad \dots \qquad (3)$$

Now, if one end of the line be put direct to earth, we must make q equal to nought in equation (2). Under these circumstances the current $-\frac{d\,v}{d\,x}$ at any point x equals

$$\frac{V}{\sqrt{t}} \frac{\epsilon^{\frac{w-x}{\sqrt{t}}} + \epsilon^{\frac{x-w}{\sqrt{t}}}}{\epsilon^{\frac{w}{\sqrt{t}}} - \epsilon^{-\frac{w}{\sqrt{t}}}} \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

and therefore the current entering the other end of the line, where the potential is V_1, say, has the value,

$$\frac{V_1}{\sqrt{t}} \frac{\epsilon^{\frac{w}{\sqrt{t}}} + \epsilon^{-\frac{w}{\sqrt{t}}}}{\epsilon^{\frac{w}{\sqrt{t}}} - \epsilon^{-\frac{w}{\sqrt{t}}}} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

If V_1 then be the potential at the point Q when the line is tested from the Q end and put direct to earth at the P end

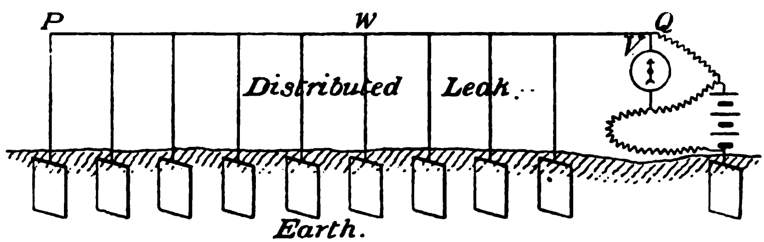


FIG. 4.

(Fig. 4), the apparent resistance of the line will be V_1 divided by the expression (5), and therefore equals

$$\sqrt{t} \quad \frac{\epsilon^{\frac{w}{\sqrt{t}}} - \epsilon^{-\frac{w}{\sqrt{t}}}}{\epsilon^{\frac{w}{\sqrt{t}}} + \epsilon^{-\frac{w}{\sqrt{t}}}};$$

but this is exactly the same as the value found in (3) for q, which made M a maximum. Hence the receiving instrument ought to have a resistance equal to the apparent resistance of the line when tested at the receiving end and put direct to earth at the sending end.

The resistance of the signalling battery does not in this case appear in the best value to give to q, but that arises from the fact that, whereas when we were dealing with a single earth fault we assumed that the signalling battery had a fixed E.M.F. and a fixed resistance, b, here we have assumed that V, the potential of the

sending end of the line, was kept constant. Now this is the same thing as supposing that the signalling battery of fixed E.M.F. has an extremely low internal resistance. The two results are therefore the same. Professor Ayrton and Mr. Whitehead.

3. Returning now to the general differential equation,

$$\frac{d^2 v}{d x^2} = \frac{v}{F(x)} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

we see that, if the distributed leak may follow any law, $F(x)$ may be any function of x. The equation therefore cannot be integrated, and we must deal with the problem of determining the best resistance to give to the receiving instrument at the end of the leaky telegraph line without actually integrating equation (1), and without expressing in an explicit form the value of the current that passes through the receiving instrument.

To ascertain the general form of the solution of the above differential equation, whatever function $F(x)$ may be, let one solution be,

$$v = \phi(x):$$

then
$$\frac{d^2 \phi(x)}{d x^2} = \frac{\phi(x)}{F(x)} \ldots \quad \ldots \quad \ldots \quad (6)$$

Eliminating $F(x)$ from equations (1) and (6), we have

$$v \frac{d^2 \phi(x)}{d x^2} - \phi(x) \frac{d^2 v}{d x^2} = 0;$$

$$\therefore \frac{d}{d x} \left\{ v \frac{d \phi(x)}{d x} - \phi(x) \frac{d v}{d x} \right\} = 0.$$

and
$$v \frac{d \phi(x)}{d x} - \phi(x) \frac{d v}{d x} = \text{some constant, say } - b;$$

$$\therefore \frac{d}{d x} \left\{ \frac{v}{\phi(x)} \right\} = \frac{b}{\{\phi(x)\}^2},$$

$$\text{or } \frac{v}{\phi(x)} = a + b \int \frac{d x}{\{\phi(x)\}^2};$$

$$\therefore v = a\,\phi(x) + b\,\psi(x) \quad \ldots \quad (7)$$

is the general form of the solution of the original differential equation, the values of the constants a and b depending on the terminal conditions. In fact, as the differential equation No. 6 is linear, it is almost obvious, without any proof, that the general solution of this equation must be of the form given in (7).

Professor Ayrton and Mr. Whitehead.

In our particular case (Fig. 3) the terminal conditions are,

when $x = 0, \quad v = V,$

and when $x = w, \quad v = V';$

also, when x equals w the current, A, flowing through the receiving instrument at the Q end of the line, or $-\frac{dv}{dx}$, equals $\frac{V'}{q}$.

$$\therefore V = a\,\phi(0) + b\,\psi(0) \quad \ldots \quad \ldots \quad (8)$$

$$\text{and } V' = a\,\phi(w) + b\,\psi(w), \quad \ldots \quad (9)$$

$$\therefore \frac{V'}{q} = -a\,\phi'(w) - b\,\psi'(w), \quad \ldots \quad (10)$$

if we write $\phi'(w)$ and $\psi'(w)$ for $\frac{d\,\phi(w)}{dx}$ and $\frac{d\,\psi(w)}{dx}$ in the usual way.

Hence, eliminating V' from equations (9) and (10),

$$a\left\{\phi(w) + q\,\phi'(w)\right\} + b\left\{\psi(w) + q\,\psi'(w)\right\} = 0 \quad (11)$$

Eliminating (b) from equations (8) and (11),

$$a\left\{\phi(0)\,\psi(w) + q\,\phi(0)\,\psi'(w) - \psi(0)\,\phi(w) - q\,\psi(0)\,\phi'(w)\right\}$$
$$= V\left\{\psi(w) + q\,\psi'(w)\right\} \quad \ldots \quad \ldots \quad (12)$$

also eliminating a from the same two equations,

$$b\left\{\psi(0)\,\phi(w) + q\,\psi(0)\,\phi'(w) - \phi(0)\,\psi(w) - q\,\phi(0)\,\psi'(w)\right\}$$
$$= V\left\{\phi(w) + q\,\phi'(w)\right\} \quad \ldots \quad \ldots \quad (13)$$

therefore, substituting in equation (7) the values of a and b given by equations (12) and (13), we have

$$v = V\,\frac{\left\{\psi(w) + q\,\psi'(w)\right\}\phi(x) - \left\{\phi(w) + q\,\phi'(w)\right\}\psi(x)}{\phi(0)\,\psi(w) + q\,\phi(0)\,\psi'(w) - \psi(0)\,\phi(w) - q\,\psi(0)\,\phi'(w)}.$$

Now A, the current flowing through the receiving instrument at the Q end of the line, is $-\frac{dv}{dx}$, where x is made equal to w; therefore

$$A = V\,\frac{\psi(w)\,\phi'(w) - \phi(w)\,\psi'(w)}{\phi(0)\,\psi(w) + q\,\phi(0)\,\psi'(w) - \psi(0)\,\phi(w) - q\,\psi(0)\,\phi'(w)},$$

and the magnetic effect is proportional to $A\sqrt{q}$, and will, therefore, be a maximum when

$$q = \frac{\phi(0)\,\psi(w) - \psi(0)\,\phi(w)}{\phi(0)\,\psi'(w) - \psi(0)\,\phi'(w)} \quad \ldots \quad (14)$$

Next, let the line be put direct to earth at the P end, and the apparent resistance of the line, with its *non*-uniformly distributed leak, tested from the Q end (Fig. 4): then, if x be still reckoned

from the P end of the line, the terminal conditions for determining the constants in the general solution, Professor Ayrton and Mr. Whitehead.

$$v = a\,\phi(x) + b\,\psi(x) \qquad \ldots \qquad \ldots \qquad (7)$$

are, when

$$x = o, \qquad v = 0,$$
$$x = w, \qquad v = V_1;$$

$$\therefore v = V_1 \frac{\phi(0)\,\psi(x) - \psi(0)\,\phi(x)}{\phi(0)\,\psi(w) - \psi(0)\,\phi(w)};$$

and since the apparent resistance of the line tested from the Q end equals V_1 divided by $\frac{dv}{dx}$, when x is made equal to w, this apparent resistance will be,

$$\frac{\phi(0)\,\psi(w) - \psi(0)\,\phi(w)}{\phi(0)\,\psi'(w) - \psi(0)\,\phi'(w)};$$

but this is exactly the same as the value of q given in equation (14), that made the magnetic effect a maximum. Hence we may conclude that, whatever be the nature of a leak on a telegraph line—whether the leak be a single one, or be distributed along the line according to any law of distribution—the same rule holds true for the best resistance to give the receiving instrument, viz., *the receiving instrument at either end should have a resistance equal to the apparent resistance of the line when tested from that end and put direct to earth at the other end.*

In what precedes it is assumed that the resistance of a coil of wire occupying a given form and volume is proportional to the square of the number of convolutions. This is absolutely true either when the thickness of the insulating covering is negligible compared with the thickness of the copper, or when the ratio of thickness of the insulating coating to the diameter of the copper is constant for each gauge of wire employed. In a paper on galvanometers* published in the *Proceedings of the Physical Society*, examples are given of similar coils of silk-covered wire of very different resistances where this proportionality of resistance to the square of the number of windings holds very well. In some other cases, however, as will be seen by referring to that paper, the resistance is more nearly proportional to the number of windings raised to the power five halves.

* "Galvanometers," by Professor Ayrton, T. Mather, and W. E. Sumpner, D.Sc., *Phil. Mag.*, July, 1890, page 86.

Professor Ayrton and Mr. Whitehead.

It is therefore worth while considering how the rule given above for the test resistance for the receiving instrument would be varied if the coil of the receiving instrument were wound with such insulated covered wire that M, the magnetic effect, instead of being proportional to $A\sqrt{q}$, were proportional to $A\,q^n$. In that case it may be shown that M will be a maximum when

$$q = \frac{n}{1-n}\;\frac{\phi(0)\,\psi(w) - \psi(0)\,\phi(w)}{\phi(0)\,\psi'(w) - \psi(0)\,\phi'(w)};$$

and this is $\frac{n}{1-n}$ times the apparent resistance of the line when tested from the receiving end and put direct to earth at the signalling end.

The President.

The PRESIDENT: At this late hour it will not be possible to discuss the paper just read, but we will do so at the next meeting.

I have to announce that the scrutineers report the following candidates to have been duly elected:—

Member:

Charles Faraday Proctor.

Associates:

Francis Edward Benest.	John William Jones.
Clement Frederick Davis.	W. F. Wardroper.

Students:

Walter Buchanan Browning.	Frederick Augustus Leigh.
William Duddell.	James Mathieson Macfie.
Herbert William Jones.	Francis Henry Merritt.

Francis Richard Wade.

The meeting then adjourned.

ABSTRACTS.

P. LENARD—ON CATHODE RAYS IN GASES AT ATMOSPHERIC PRESSURE AND IN HIGH VACUA.

(*Wiedemann's Annalen, Vol.* 51, *No.* 2, *p.* 225.)

When a Geissler tube is sufficiently exhausted, almost all phenomena connected with the anode disappear, and the rays which cause phosphorescence, and which start from the cathode, reach their highest development; these were discovered by Hittorf, and studied by Crookes as radiant matter. .These rays, although produced by electric discharge, are completely independent in their propagation; and although resembling light rays in the geometrical relations of their propagation, yet they differ from light in many important characteristics—for instance, in their power to penetrate solid bodies, while finding the glass walls of the tube opaque. The author inquires what would happen if the tube were made transparent to the rays. Hertz discovered that ordinary metal foil was quite transparent to the cathode rays, even in triple and quadruple layers, and the author found even 15-fold aluminium foil still transparent. He therefore constructed a Geissler tube so arranged that the cathode rays, proceeding in straight lines along the length, fell at the other end on a small window of aluminium foil, about eight times the usual thickness, quite free from holes, and capable over its small area (1·7 mm. diameter) of withstanding full atmospheric pressure. In front of this window, in the path of the rays, stands a diaphragm having a hole 3 mm. in diameter, thus preventing the window from corrosion by acting as anode. The whole apparatus was enclosed in an earthed tin case, leaving only the window free; and the tube was connected to a Geissler pump. Suitable arrangements were made for controlling the induction coil, and maintaining the vacuum at the most favourable amount for the production of cathode rays.

Cathode Rays in Air.—When the cathode rays are started, they come through the window into the open air, which is faintly illuminated by a bluish glow brightest at the window, and extending about 5 cm. in every direction; the window itself is dark when new, but becomes faintly phosphorescent after use, owing, probably, to the formation of oxide on the outside. All bodies capable of phosphorescence glow on the side turned to the window if held near it, with the light peculiar to them; in the the powerful light of the alkaline earths, of calcspar and of uranium glass, the air and window glow completely disappear. The intensity of the phenomenon decreases with increasing distance from the window, and disappears at 6 to 8 cm. away. The intensity is determined only by distance, and not by direction, as was to be expected, for Hertz observed that cathode rays are diffused in passing through aluminium. A phosphorescent screen, made of tissue paper soaked in pentadecyl-para-tolyl-ketone, and held edge on to the window, glows brightest at the window, and decreases in phosphorescence uniformly, points of equally intense illumination lying on circles having the

window as centre. In these cases the colour and relative intensity of the glow is the same as in an ordinary vacuum tube. A tube of glass or tinfoil, placed coaxially with the rays between the window and the phosphorescent body, rather diminished than increased the glow. If the cathode rays were deflected from the window by means of a magnet, all the phosphorescence phenomena ceased in the observing space. Light and feeling are unaffected by cathode rays, but the smell of ozone is strong, and the peculiar taste produced on the tongue may also be attributed to the ozone.

A moderate-sized plate of quartz, half a millimetre thick, held between the window and the glowing body, extinguishes the light, but genuine or imitation gold and silver or aluminium foil is transparent to the rays: the air glows in front of, but not behind, the quartz plate; it glows on both sides of the metal foil, which itself is dark. These are characteristic differences between cathode rays and light; but it is not to be concluded that quartz would not be transparent also if it could be made as thin as the metals, which are themselves opaque if ½ mm. thick, as are all solid bodies; on the other hand, all solids procurable in very thin films were more or less transparent. A double thickness of tissue paper casts a shadow, whatever colour it is; drawing paper is almost, and cardboard 0·3 mm. thick quite, opaque. Films of glass begin to be appreciably transparent when 0·02 mm. thick, and are perfectly transparent when thin enough to show Newton's rings—that is, when as thin as double aluminium foil. There is thus no appreciable difference between conductors and dielectrics. Mica and collodion films are also transparent when about 0·1 mm. thick. A glass window could be used if sufficiently thin, and did as well as aluminium, but is not so easily manipulated. With regard generally to opacity in air, the author finds no such differences as occur in the case of light, all substances being more or less equal in their qualities in this respect.

The apparent contradiction with the experiments of Crookes and of Goldstein, who found glass and collodion opaque even in thin films, is explained by the blaze of light from the phosphorescent glass in their vacuum tubes, which makes the shadow of the film appear dark by contrast.

The air is a turbid medium for cathode rays, as is shown by experiments on shadows of solid objects, which are never sharp. The phenomena resemble light penetrating a vessel of milk. Cathode rays are actinic, and will darken sensitive paper about as quickly as light on a cloudy day; and experiments on quartz and foil are easily carried out with dry plates, when the curious transparency of the latter and opacity of the former are fully brought out; and the dry plate is more sensitive than the eye, owing to the cumulative nature of the effect, relatively opaque bodies being thus shown to be partially transparent.

Chemical effects, other than a change of colour of iodine paper, which may have been due to ozone, were not observed. Electrolytic oxygen and hydrogen were not exploded; carbon bisulphide did not catch fire. A thermopile, so sensitive as to discover a candle 50 feet away, remained unaffected.

Cathode rays penetrate the interior of metallically closed spaces, and are easily separable from the electrostatic forces producing them. The screening arrangement described above does not prevent small sparks being drawn from

conductors in the observing space, and these are produced even when the cathode rays are deflected by a magnet so that phosphorescence phenomena cease. It was also found that the cathode ray phenomena took place in precisely the same manner in the interior of a completely closed metal box fastened to the front of the window, and inside of which there were no electrostatic forces. The photographic plate exposed in this box showed also that the air glow was present, and was therefore connected with the cathode rays, and not with the electric forces.

Electrified bodies placed in the observing space lose their charge; but an unelectrified body does not acquire any charge capable of being observed with a most delicate electroscope. Quartz is opaque and aluminium foil transparent to this effect, as before.

Cathode Rays in a Vacuum.—When a tube reaches a high state of exhaustion, no electric discharge takes place in it, and no cathode rays can be produced; consequently it was unknown whether matter was essential for the propagation of the rays; but by making the vacuum at the observing space outside the window this point could be settled. The vacuum tube was therefore constructed with a prolongation beyond the window connected to a pump which was capable of producing the highest vacua, and since these vacua were maintained for hours, there was no leakage from the discharge tube through the window. If the degree of exhaustion in both tubes is the same—*i.e.*, about the vacuum used by Crookes—the following phenomena are observed:—The glass of the observing space tube glows bright green up to the first diaphragm placed in it and a little beyond, and also a short way up the exhaust tube, which enters in this portion of the tube. This corresponds to a propagation of the rays in all directions from the window in straight lines. Beyond the diaphragm all is dark except a patch about 9 mm. in diameter at the end, due to the rays passing through the hole in the diaphragm; these can be deflected and the spot moved about by holding a magnet near. If it falls on a small electrode placed at the extreme end of the observing tube, it disappears completely. If the tube were further exhausted of the "turbid" air, the rays went for 30 cm. without appreciably weakening in intensity, and they behaved as they do in an ordinary vacuum tube towards a magnet. On further exhaustion of the observing tube to such a degree that no discharge passes if the electrode and the diaphragm of the observing tube are connected to the induction coil, the cathode rays go through it as before with perfect ease. The phosphorescent spot is as bright as before, and has perhaps sharper boundaries; the phosphorescence of the glass between window and diaphragm continues as before. After the passage of the rays the vacuum was just as good as before—no matter had entered with them. An observing tube 1½ metres long was now made, and connected to a Töpler-Hagen pump—suitable diaphragms allowed only a small pencil of rays to pass through—and the tube was exhausted for several days with repeated heating until the pump, which was provided with a capillary tube (Raps, *W. A.*, vol. xliii., p. 636), had reached its limit. A movable phosphorescent screen beyond the diaphragm showed the diameter of the spot covered by the rays at various distances, and this corresponds to a propagation in absolutely straight lines, as in the case of light. The vacuum in these experiments corresponded to the pressure of mercury vapour at $-21°$ C., to which it was artificially cooled—that is, to 0·00002 mm. Cathode rays, therefore

are propagated through spaces containing matter only in such an attenuated form that all its known effects cease: that is to say, they are phenomena in the ether, as was long ago concluded by E. Wiedemann, Hertz, and Goldstein.

Cathode Rays in Gases.—The transparency of gases varies, and depends on their densities, as seen in the following table giving the distances to which the rays penetrate the gases at atmospheric pressures:—

Gas.	Density.	Length of Ray.
Hydrogen	1·0	29·5
Nitrogen	14·0	6·5
Air	14·4	6·0
Oxygen	16·0	5·1
Carbonic acid	22·0	4·0
Sulphurous acid	32·0	2·3

The transparency increases with decreasing density, and at a pressure of 0·07 mm. air and hydrogen have the same length of ray—about 12 times that of hydrogen at atmospheric pressure. The glow decreases rapidly in intensity as it gains in extension; this being what would be expected if gases are turbid media. The degrees of turbidity were also compared by observing the diffusion of a pencil of rays after passing through a diaphragm.

All these cathode rays were produced in the same manner at the same pressure; at different pressures other kinds were produced which were diffused to different extents in the observing tubes. If the discharge tube were a little further exhausted, the rays were still produced, but were less diffused, and *vice versâ;* and these phenomena were frequently observed while bringing the discharge tube to the proper degree of exhaustion. Hertz has already observed that there exist different kinds of cathode rays having properties corresponding to the colours of light, and differing in their capacity for exciting phosphorescence, for absorption, and deflection by a magnet; and generally the phenomena here described correspond with those of light. Light of short wave-length is more scattered in certain optical media than that of longer wave-length.

To judge from the behaviour of gases here described, the occurrences in the ether which constitute the existence of the cathode rays must be of such delicacy as to compare with molecular dimensions in order of magnitude. Matter behaves as if it filled all space as far as light, even of smallest wave-length, is concerned; but even elementary gases behave towards cathode rays as non-homogeneous media: every molecule appears to be a separate obstruction. Molecules of gas obscure the ether, the extent of the turbidity depending only on the total mass of the molecules per unit of volume; and the phenomena are to some extent reproduced if the cathode rays are replaced by light, and the molecules by coarse particles of matter. This very important paper is fully illustrated.

W. KUNZ—ON THE DEPENDENCE OF MAGNETIC HYSTERESIS, PERMEABILITY, AND THE ELECTRICAL CONDUCTIVITY OF IRON AND NICKEL ON THEIR TEMPERATURE.

(*Beiblätter, Vol.* 18, *No.* 2, *p.* 229.)

The author measured the temperatures in his experiments by means of a

thermo-couple of platinum and platinum containing 10 per cent. of rhodium. The temperatures were produced by means of platinum wires carrying currents wound round the wire under experiment, and which went up to over 800° C. The wire can thus be maintained at a perfectly even temperature. The author comes to the following conclusions:—The work done in overcoming hysteresis in a magnetic cycle of given amplitude for soft iron varies with the temperature, becoming smaller with increasing temperature. For steel, on the other hand, the work increases, slightly at first, up to 300°, then falls again, at first very quickly, but with decreasing rapidity. For nickel the hysteresis loss decreases, at first rapidly, afterwards more slowly, with increasing temperature. For soft iron the relation of hysteresis loss, H, to temperature, t, may be expressed thus: $H = a - b\,t$; a and b being constants depending on the quality of the iron, and independent of the maximum induction of the cycle. After cooling the wire to its original temperature, the hysteresis is no longer so great as before the heating. If the cycle be repeatedly performed at a high temperature, the hysteresis loss is considerably reduced.

ANON.—THE LIVEING CARBON ELECTRODE.

(*La Lumière Electrique, Vol.* 51, *No.* 7, *p.* 331.)

In M. Liveing's electrolysing apparatus, the anodes consist of pieces of retort carbon resting on an insulating grid. These pieces of carbon are connected to the positive pole by a metallic rod, which is pressed down on to the carbon by means of a weight. A cheap anode is thus obtained, possessing a large surface.

ANON.—INDUSTRIAL ELECTRO-CHEMISTRY.

(*La Lumière Electrique, Vol.* 51, *No.* 9, *p.* 429.)

By the same method as that of MM. Hermite and Dubosc, M. Despeisses proposes to manufacture potassium and sodium by electrolysing their chlorides. The cathode consists of a bath of mercury, which amalgamates with the sodium and potassium, and yields a product from which, by quickly washing with boiling water, potassium and sodium can be obtained.

J. GARNIER.—THE STUDY OF CHEMICAL REACTIONS BY MEANS OF ELECTRICITY.

(*La Lumière Electrique, Vol.* 51, *No.* 13, *p.* 619.)

The measure of electrical conductivities has been of aid in following certain chemical reactions.

On this principle M. J. Garnier has studied what takes place during the reduction of metallic oxides by means of carbon. In a fire-clay tube was placed a mixture of oxide of nickel and powdered charcoal, piled up to a few centimetres between two conductors of mild steel; the tube being heated up by means of coke. Before heating it, 50 volts were maintained between the two conductors; the resistance was very high, no current being read on the ammeter. After a quarter of an hour's heating, the process of reduction was started, and the current gradually rose to 50 amperes, the voltage becoming very small, the particles of nickel evidently forming a path of very low resistance.

If the process of heating is carried further, the reduced metal is carbonised, the resistance is increased, and the current falls to 1 or 2 amperes with about 45 volts.

M. Garnier has also experimented in the same manner with mixtures of oxide of copper, of nickel, and of iron. Such a method should be of service in such metallurgical processes as the manufacture of steel, and in copper and nickel refining.

ANON.—THE LAHMEYER SYNCHRONISER.

(La Lumière Electrique, Vol. 51, No. 10, p. 483.)

This instrument is for use with alternating motors. It consists of a piece of iron fixed to the end of a spring which is attracted by a magnet pole. This piece of iron will vibrate and make a noise when the motor is out of synchronism. When synchronism is reached the noise stops.

J. BOURQUIN—THE EMPLOYMENT OF GAS ENGINES IN PUBLIC AND PRIVATE ELECTRIC LIGHTING STATIONS.

(La Lumière Electrique, Vol. 51, No. 5, p. 483.)

The author states the following advantages of using gas engines for electric lighting purposes:—

1. The gas works themselves may be used as a central station.
2. The facility with which gas can be obtained from existing sources.
3. It has been shown that one cubic metre of gas gives—
   - (*a*) In a Bengel jet of 16 candle-power, a maximum of 91 candle-hours;
   - (*b*) In an incandescent lamp of 16 candle-power, a minimum of 162 candle-hours;
   - (*c*) In the Wenham lamp, a maximum of 200 candle-hours;
   - (*d*) In an arc lamp, a minimum of 654 candle-hours;

the result being that the number of 16-candle-power lamps can be increased in the ratio of 91 to 162 if incandescent lamps be used, and in the case of arc lamps in the ratio of 200 to 654, without increasing output of station.

4. If the electric lighting is carried out by the gas company, a smaller staff will be needed than in the case of an independent company.

5. Together with the above technical advantages, it is necessary to consider the advantages of combining both systems of supply, thus obviating such competition as would be detrimental to the success of the new undertaking. Moreover, gas will under these conditions be obtained for the engines at the cost of production, and not at the selling price.

A. HESS—THE ELECTRIC TRAMWAY FROM BORDEAUX-BOUSCAT TO VIGEAN.

(La Lumière Electrique, Vol. 51, No. 5, p. 201.)

This electric tramway is on the Thomson-Houston system. The total length of line is 4,820 metres. The rails have a gauge of 1 metre. The sleepers, as well as the rails, are of steel. The gradients are small, and vary from 2 to 15 mm. in the metre. There are few curves, the smallest radius being about 40 metres. A single track is used, with seven points, excluding those at the extremities of the line; the smallest distance between the points is 300 metres, and the greatest distance 1 kilometre. The conductor is placed overhead, and consists of a hard copper wire of high conductivity, 8½ mm. diameter. This wire is suspended over the centre of the track, either by galvanised steel cables fixed to posts of wood or steel, or the wire is suspended from brackets fixed to wooden posts. The rails and earth are used as a return. The generating station is situated about centrally from the two extremities of the line. The carriages are stored in the same building. The central station proper consists of a machine room and boiler house.

Steam is obtained from two Babcock-Wilcox boilers, having a heating surface of 132 square metres, each capable of evaporating 1,850 kilogrammes of water per hour.

The feed water is contained in a tank, and passes through a heater before entering the boiler. A Worthington pump is used for pumping water up from a well into the tank.

The engine room contains two compound non-condensing engines, by McIntosh & Seymour, of New York, driving two Thomson-Houston generators by belt. These engines have tandem cylinders, with valve chests on alternate sides of the cylinders, allowing of freer access to these parts, as well as to the stuffing boxes between the cylinders. These are completely steam-jacketed. Lubrication of the engine is effected by means of oil pumps. The engines are capable of developing 150 H.P. at 235 revolutions per minute.

The dynamos are of the Thomson-Houston four-pole type, over-compounded. Their output is 100 kilowatts at an E.M.F. of 550 volts and a speed of 600 revolutions per minute.

The distributing board consists of two panels. These contain the main and shunt switches, a device for connecting up the compound machines, a shunt rheostat, a voltmeter, an ammeter, five pilot lamps, a lightning protector, and an

automatic cut-out for use in the event of an accidental short-circuit. At the side of the switch-board are placed the two Thomson-Houston meters and a Weston voltmeter with an engine-room dial.

The cars in use are of two kinds. Those fitted with motors weigh 5 tons, and can accommodate 40 people. They have no seats outside. The others are of the same design, and capable of carrying 50 passengers. These have no motors, and are destined to be drawn by the motor carriages during periods of heavy traffic. The wheels are 0·84 mm. diam. The weight of 5 tons is made up as follows:— Motor and gearing, 900 kgm.; the carriage, 2,000 kgm.; truck, 1,500 kgm.; various parts, 600 kgm.

Six of the motor cars are in use.

The motors are of the Thomson-Houston "waterproof" type, capable of developing 15 to 20 H.P. The gearing works in an oil box. The armature is completely closed in by an iron shell forming part of the magnet system. The cars are lighted by five incandescent lamps connected in series across the 500-volt circuit.

Under ordinary circumstances the company runs 20 trains per day in each direction. The mean speed is 12 kilometres per hour, but this figure can be considerably increased.

P. HOHO—MEANS OF PROTECTION AGAINST LIGHTNING.

(*La Lumière Electrique, Vol.* 51, *No.* 5, *p.* 210.)

Official German reports show that the number of deaths caused by lightning have increased by about 200 per cent. from the year 1870 to 1882. The author attributes this fact to the gradual disappearance of forests, and to the greater use of metals in building construction. Lightning protectors have yielded excellent results in most cases, and it is essential that all high buildings should be provided with them. There are in general use two types—

1. The Frankling lightning protector.
2. The Melsens lightning protector.

The former is the older of the two, dating as far back as 1752. It consists of a metal rod placed above the building and connected with a continuous conductor, which must be well earthed in a place where the soil is damp, otherwise accidents may occur. It is also important that the tep of the protector should tower well above all other points on the building. This does not, however, afford absolute protection, for in many instances have buildings been struck which were provided with them.

The second system, due to Melsens, is of a more recent date, and not so well known. It depends on the following principle:—That if a building were surrounded by a metallic screen which was well earthed, it would be absolutely protected against lightning. This condition is easily realised in practice. The salient points of the building—preferably metallic parts—must be judiciously connected by a metallic circuit, which must be earthed at a number of points. It is also advisable

to fix metallic forks above this circuit. The latter may be of large galvanised iron wire, phosphor-bronze, or copper. The use of the forks is to prevent a discharge, and to neutralise the charge in the clouds to a certain degree. That such an action takes place has been conclusively proved by M. Courtoy.

The existence of such a protector has no influence on neighbouring buildings.

There is a great economy in this system, as the circuit and forks may be made light, and consequently easily fixed. The difference in price between the two systems is considerable.

Owing to the number of paths to earth through the building, less attention is required than with the other system. The author states that no building, to his knowledge, has ever been struck by lightning which was carefully fitted with such a system, and where Melsens's principles had been observed. This system is largely used in Belgium; it has been recommended by L'Académie des Sciences in France, notably for powder factories and magazines; and has also been adopted in England for protecting ships.

E. J. BRUNSWICK—NOTES ON THE ELECTRICAL INDUSTRY IN THE UNITED STATES.

(*La Lumière Electrique, Vol.* 51, *No.* 9, *p.* 414.)

Electric Traction.

The present tendency is to use heavy rails, 0·15 metre high, weighing from 38,500 kilos. and upwards per metre. The rails are fixed on oak sleepers, placed about 0·75 metre apart. At the joints the sleepers are brought close together. In some instances lately, rails 0·22 metre high have been employed, and nailed directly on to the sleepers. When there is more than a 10 minutes' interval between the cars a single line is used.

Slopes of 10 and 12 per cent. are to be found. The minimum radius for curves is 9 metres, and the resistance offered by these curves is estimated as equivalent to a 4 per cent. increase in the slope. Overhead conductors with earth return are mostly used.

Owing to the high value of land in the proximity of town, it is usual to find the generating station at the end of the line. The generating stations generally contain at least two steam engines, except when less than five cars are run. Up to 15 cars it is preferred to use high-speed engines, owing to the variations in load.

Usually the number of cars is considerably above this; it is then that Corliss or similar engines are used. For more than 40 cars compound condensing engines are employed. With respect to the output of the station, it is estimated that for five to 10 cars (using 25-H.P. motors) 30 amperes per car are required, and 25 amperes per car (using 20-H.P. motors) for 10 cars or more; the difference of potential being uniformly 500 volts.

The generating stations are very similar to one another. The West End Street Railway Co. of Boston should be taken as a fine example. This station is arranged as

follows:—Ground floor: steam engines; basement: mains, pumps, condensers, and economisers; top floor: dynamos. The boiler house is adjacent to the machine room, and contains two fine batteries of six groups of double boilers. These are of the Babcock type, and are each of 250 H.P., making a total of 6,000 H.P., but are capable of maintaining an overload of 50 per cent. when continuously working. Coal is run in to the boiler house directly from a neighbouring wharf. Six triple-expansion Corliss engines of 1,000 H.P. are installed. The dynamos, under normal conditions, give 500 amperes at 550 volts, and can stand during several hours a 50 per cent. overload.

Preference is given in America to simple reduction motors, in view of their lightness and higher efficiency. The mean speed of the cars is 16 to 20 kilometres per hour. In some cases the maximum speed is 40 to 45 kilometres per hour.

The motors have mostly drum-wound grooved armatures. In many cases four-pole motors are used. Breakdowns are fairly frequent, due to dust or moisture injuring the motor commutators.

The Westinghouse and Thomson-Houston motors have their spindles parallel to the axles of the carriage, the speed being geared down from 10 to 7. The Short Electric Co. either gears down or drives direct.

The Sperry Electric Railway Co. (Cleveland, Ohio) uses only one motor per car, with its spindle at right angles to the axles; reduction in speed being effected by bevel gearing.

The Short Electric Co.'s Motors.

When the armature is worked directly on the axle, the average speed is about 150 revolutions per minute. The velocity of the car is from 10 to 15 miles per hour; the number of revolutions per minute is 112 to 170 for wheels of 0·75 metre diameter, and 106 to 160 for wheels 0·80 metre diameter. The armatures are of the Paccinotti type. Eight field magnets are used, placed face to face on each side of the armature. The armature has a hollow spindle, through which passes the axle.

Each car carries two motors of 20 H.P The chief inconvenience of these motors is the large diameter of the armature, which necessitates the use of wheels 0·9 metre in diameter. The latest type are used with wheels 0·775 metre in diameter, and weigh about 1,150 kilogrammes. The magnets are of cast steel. There are three field magnets, with consequent poles, constituting a six-pole machine of special shape.

The armature is 0·525 metre in diameter, and runs at 120 revolutions per minute, and gives 20 H.P. The motor is so mounted that it is an easy matter to replace damaged sections on the armature.

A short motor with six poles, giving 20 H.P. at 500 volts, has the following dimensions and particulars:—

Diameter of armature	0·55 metre.
Weight	1,150 kilogrammes.

Over-all dimensions:—

Length	1·050 metres.
Width	0·950 „
Height	0·650 „

A motor is also made by the same company for simple reduction, and is somewhat analogous to the Shuckert machine. The armature is of the disc type, with eight field magnets. The magnetic circuit is of cast steel, in which the induction is pushed up to 20,000 C.G.S. units per square cm. The commutator has 144 sections.

OVER-ALL DIMENSIONS.

Size, 500 Volts.	Diameter of Armature.	Weight.	DIMENSIONS.		
			Length.	Width.	Height.
20 H.P.	0·465 m.	950 kg.	0·600 m.	0·530 m.	0·560 m.
30 H.P.	0·515 m.	1,150 kg.	0·620 m.	0·700 m.	0·590 m.

THE SPERRY ELECTRIC RAILWAY CO.'S MOTOR.

This company have designed a motor with the special intention of eliminating all shocks and vibrations which are detrimental to the armature. Only one motor is used on each car, and gears at each end of the spindle with the axles by means of bevel gearing. Careful tests carried out by the makers have shown that the power lost with uncut bevel gearing is only 1·74 per cent. above that with carefully cut spur gearing. It is estimated that this system of driving gives 11 per cent. increase of tractive force, as compared with the system of driving each axle by a separate motor. This is due to the identity in speeds of the two axles obtainable by using only one motor, which is very noticeable on slopes, at starting, or during wet weather.

The whole weight of the motor rests on two cross bars supported on the truck by springs. The level gearing is necessarily supported by the axle.

Such cars have worked satisfactorily at Pittsburg with slopes of 6 and 10·5 per cent.

The cars are generally 4·80 metres long, and weigh 8,350 kilos. when fully loaded. Long cars of 6 metres to 6·6 metres are sometimes used. For use on large slopes the cars carry sand boxes to increase adherence, which must be from 125 to 150 kilos. per ton in bad weather.

The following table gives the capital and other particulars of some of the large companies :—

	Companies.	Capital in Francs.	Miles.	Maximum Slope.	No. of Motor Cars.	Total Output of Generating Station.	Remarks.
Brooklyn.	Atlantic Av. R. & Co.	6,000,000	42	6 %	50	1,750	Original station.
	Do. do.	...	...	6 %	500	10,000	New station.
	Brooklyn City R. R. Co.	...	14	...	40	200	
Newark.	Essex Co....	...	2·2	...	4	150	
	Newark South Avenue Co.	7,500,000	13	5	50	1,000	
	Rapid Transit Star Co.	2,500,000	10	...	16	400	
Pittsburg.	Pittsb., Knoxville, St. Clair Ry. Co.	...	1·5	10	10	300	
	Citizens' Traction Co.	1,750,000	7	...	30	275	Only 15 motor cars
	Duquesne Traction Co.	15,000,000	68	7	40	4,700	
	Federal Street Railway Co.	6,500,000	22	6·1	75	1,200	60 motor cars.
	Pittsburg Traction Co....	...	2	13·2	6	100	2 motor cars.
	Pittsburg, Allegheny, Manchester Ry.	...	...	...	65	1,000	
	Pittsburg and Birmingham Ry. Co.	15,000,000	7	...	65	4,200	
	Schenley Park Ry. Co.	500,000	2	5·5	2	200	
	Suburban Rapide Circuit	600,000	25	2·4	...	250	7 motor cars.
Chicago.	Calumet Tl. Ry. Co.	2,500,000	38	...	100	1,300	40 motor cars.
	Cicero and Puvis St. Ry. Co.	5,000,000	26	...	54	500	Do.
	Sonth Chicago City Ry. Co.	500,000	30	2	26	300	Do.
	Wester South Towers St. Ry. Co. ...	2,500,000	12	...	12	...	Being constructed
Boston.	Boston and Revere El. Co.	250,000	4·3	7	14	150	5 motor cars.
	West End Street Ry. Co.	68,000,000	259	7·26	500	12,000	500 motor cars.

After taking a careful mean, the following results have been arrived at:—In towns of 20,000 to 30,000 inhabitants, 30 services are made per individual per annum, at a cost of 7·50 francs per head;

From 40,000 to 60,000	inhabitants,	59	services, at	15·00 francs per head.
„ 100,000 to 200,000	„	129	„	31·15 „ „
„ 400,000 to 800,000	„	164	„	41·10 „ „
„ 800,000 to 1,500,000	„	190	„	47·55 „ „

The weights of copper used for lines of variable lengths, with cars running at five-minute intervals, are as follows:—

Distance in Kilometres.	Total Weight of Copper in Kilogrammes.
4	1,072
8	7,702
10	13,362
16	61,504

In arriving at these figures the mean speed was taken as 14·4 kilometres per hour, with 25 amperes at 500 volts per car; the loss in feeders at 15 per cent.

ANON.—THE KNŒFFLER & GEBAUR SYSTEM OF ELECTRIC BLEACHING.

(*La Lumière Electrique, Vol.* 51, *No.* 10, *p.* 480.)

It is necessary with this process to use a 10 or 15 per cent. solution of chloride of sodium, through which an electric current is passed with a current-density of 600 amperes per square metre of electrode: hypochlorite of lime is then produced in solution with an increase of temperature of—

15°	... ...	0·30 per cent. of active chloride;
21°	... ...	0·40 ,, ,, ,,
28°	... ...	0·50 ,, ,, ,,

It is then known, for example, that a dissolution of 0·40 per cent. will take place if the rise of temperature is 21°, and if this temperature be maintained by suitably admitting liquid into the bath. The reaction takes place, according to the inventors, with perfect regularity, without the use of diaphragms or addition of lime.

ANON.—AUTOMATIC APPARATUS FOR STARTING GAS ENGINES.

(*La Lumière Electrique, Vol.* 51, *No.* 7, *p.* 333.)

The object of this invention is to start a gas engine with certainty, and without fear of explosion if either light or heavily loaded. The apparatus is applicable to engines of any power, and does away with the necessity of pulling round the fly-wheel or using an auxiliary motor.

This result is obtained by initially exploding a mixture of gas and air in the cylinder of the engine. The pressure of this initial charge may be regulated at will, and must be sufficient when exploded to overcome the static resistances of the engine and machinery with which it is geared.

The starting apparatus consists of—

1. A hand pump, used for introducing the mixture of gas and air into the cylinder of the engine, and into a small auxiliary cylinder.

2. A device for holding the fly-wheel during compression.

3. An auxiliary cylinder with a small piston, used for releasing the fly-wheel.

It is at first necessary to pump out air or products of combustion from the cylinder, and to then pump in the mixture of gas and air. The mixture is ignited by an electric spark. An explosion takes place first in the auxiliary cylinder, thus releasing the fly-wheel, which is started by the compressed gases in the main cylinder; this charge is exploded directly afterwards by a valve connecting the auxiliary cylinder with the main cylinder.

Before starting it is necessary to see that all parts of the engine are under normal working conditions.

This apparatus is used at the Reims central station, where 80-H.P. engines are installed. These engines burn 14,500 litres of gas per hour when running light, and 45,000 litres at full load. The initial pressure for starting is 3·8 kilogrammes per square centimetre.

A. BLONDEL—A NEW SIMPLIFIED METHOD FOR CALCULATING POLYPHASE ALTERNATING CURRENTS.

(*Comptes Rendus, Vol.* 118, *No.* 8, *p.* 404.)

The author's object is to render the calculations of polyphase currents as simple as those of monophase currents.

The method starts with the two following hypotheses :—

1. That alternating currents all vary according to some harmonic law.

2. That the rotating magnetic field produced by a system of harmonic polyphase currents, symmetrical both in intensity and phase, has, in virtue of the good design and secondary reactions of the machine, an intensity and an angular velocity sufficiently constant that the flux cut by any one of the polyphase windings should vary also according to some harmonic law.

From these hypotheses the two following statements may be made :—

1. A rotating magnetic field may be represented by a vector, representing the direction in which the induction is a maximum at any given moment, and also the constant value of this maximum.

2. The polyphase currents producing it may also be collectively represented by a single vector, standing for the intensity of an equivalent rotating current passing round the whole circuit; in the same manner the whole of the alternating electro-motive forces may be represented by a single rotating electro-motive force, or vectorial. If q be the number of polyphase currents employed, I_0 their maximum amplitude, U_0 their maximum tension measured between each conductor and the return conductor, then the vectorial intensity, I, and the vectorial tension, U, may be defined as by formulæ (1) and (2)—

$$(1)\ I = I_0 ;$$

$$(2)\ U = \frac{q}{2} U_0 .$$

The value, ϕ, of a field may always be expressed in terms of the vectorial intensity, I, of the system producing it, and so also the vectorial electro-motive force, E, as a function of a field, F, which is producing it, by means of the two expressions—

$$(3)\ \phi = \frac{\pi}{R} I K ;$$

$$(4)\ E = \frac{k}{4} \frac{2\pi}{T} N F ;$$

where R is a magnetic resistance, K and k two coefficients depending on the type of winding.

By comparing the two formulæ (3) and (4) one obtains the theoretical expressions for the coefficient of mutual induction, M, of two polyphase systems, and of the self-induction, Λ—

$$(5)\ M = K k \frac{4\pi}{R} \frac{N_1}{2} \frac{N_2}{2} ;$$

$$\Lambda = K k \frac{4\pi}{R} \left(\frac{N_1}{2}\right)^2 .$$

The above simple definitions will allow of the application of all the ordinary laws and graphical methods used in the case of monophase alternating currents, to vectorial currents.

M. MAX LE BLANC—THE MINIMUM E.M.F. NECESSARY TO PRODUCE DECOMPOSITION IN ELECTROLYTES.

(*Comptes Rendus*, *Vol.* 118, *No.* 8, *p.* 411.)

The author claims priority to M. Nourisson's researches, for nearly three years ago experiments were carried out by him to determine the minimum E.M.F. necessary to produce visible decomposition in electrolytes by introducing a very sensitive galvanometer in circuit, and by using known electro-motive forces, increasing from 0 volts in steps of 0·02 volts. Platinum wires were used as electrodes, and it was only when the E.M.F. was raised to certain values that the galvanometer indicated any current. This critical voltage could be measured accurately in hundredths of a volt, and is called by the author the point of decomposition of the electrolyte.

These values are tabulated below, when using normal solutions of the following salts:—

	Cl.	Br.	I.	SO_4.	NO_3.	CO_3.
Potassium ...	1·96	1·61	1·14	2·20	2·17	1·74
Sodium	1·98	1·58	1·12	2·21	2·15	1·71
Lithium	1·86	1·58	1·12	2·21	2·11	1·71
Calcium	1·89	1·58	1·12	2·21	2·11	1·71
Strontium ...	2·01	1·58	1·12	2·21	2·28	1·71
Baryum	1·99	1·58	1·12	2·21	2·25	1·71
Ammonium ...	1·7	1·40	0·88	2·11	2·08	1·71

The author has also experimented with different acids and bases, and the point of decomposition was found to have in most cases the value 1·70 volts. The author considers that this is due to the decomposition of water, forming here a primary, and not a secondary, action.

M. BERTHELOT—OBSERVATIONS ON THE ABOVE: LIMITS OF ELECTROLYSIS.

(*Comptes Rendus*, *Vol.* 118, *No.* 8, *p.* 412.)

The author recalls certain results published in 1882 on the limits of electrolysis. It was shown by experiment that in the electrolysis of an alkaline salt of which the acid and the base are neither oxides, nor reduced during the operation, the minimum electro-motive force necessary to produce electrolysis is the sum of two quantities—one of them equivalent to the heat absorbed by the separation of the acid and base in solution, and the other to the heat of decomposition into oxygen and hydrogen of the water which dissolves the salt. In the case of sulphate of potassium, for example, the sum of the two heat quantities is equal to

$$15{\cdot}7 \text{ cal.} + 34{\cdot}5 \text{ cal.} = 50{\cdot}2 \text{ cal.}$$

when 1 gramme of hydrogen is liberated.

As 1 volt is equivalent to 23·2 calories, the minimum electro-motive force necessary to decompose sulphate of potash will be, according to the above law, 2·16 volts. The author experimentally found 2·20 volts, or 51 calories.

M. Le Blanc by another process obtained 2·20 volts. The above deductions are strictly applicable to all alkaline salts, so long as there exists no oxidising or reducing action at the poles.

The author also experimented with haloid salts, and obtained very varying figures for the different salts.

For chloride of potassium, the values 46·7 calories, or 2·01 volts, are obtained by calculation.

By experiment the author in 1882 found 1·98 volts; M. Le Blanc in 1891, 1·96 volts; M. Nourisson in 1894, 1·94 volts.

For bromide of potassium, calculation gives 40·8 calories, or 1·74 volts.

The author in 1882 experimentally obtained 1·73 volts; M. Le Blanc in 1891, 1·60 volts; M. Nourisson in 1894, 1·74 volts.

For iodide of potassium, calculation gives values 26·9 calories, or 1·16 volts.

The author in 1882 experimentally obtained 1·16 volts; M. Le Blanc in 1891, 1·14 volts; M. Nourisson in 1894, 1·15 volts.

From these results and many others it is seen that the concordance between electrical and thermo-chemical data, with reference to the limits of electrolysis, is very satisfactory.

ANON.—TESLA'S METHOD OF COMPENSATING FOR THE SELF-INDUCTION OF A COIL.

(*La Lumière Electrique, Vol.* 51, *No.* 9, *p.* 432.)

The effects due to self-induction may be neutralised by suitably adjusting the capacity of the circuit. To avoid using auxiliary condensers Mr. Tesla devised a method of winding bobbins which would give them a capacity of their own. As is known, the self-induction and capacity of any coil will compensate one another at a certain frequency. In ordinary coils the difference of potential between adjacent turns is very small, so that the capacity is small and can only be effective at high frequencies. To increase this capacity Mr. Tesla so winds the coil that the difference of potential between the turns is greater, and consequently also its capacity for storing energy. A coil wound in the ordinary manner with 1,000 turns for 100 volts has one-tenth of a volt difference of potential between adjacent turns.

Mr. Tesla so winds the coil that there is a difference of potential of 50 volts between adjacent turns, and the power stored in the coil due to its capacity will be 250,000 times greater as it increases with the square of the potential difference.

This system also offers the advantage of a more uniformly distributed capacity and self-induction in the coil.

E. SEMMOLA—A FEW EXPERIMENTS ON RADIOPHONY.

(*La Lumière Electrique, Vol.* 51, *No.* 13, *p.* 615.)

In these experiments the author first employed an Argy microphone. This consists of a small cylindrical box of white metal 8 mm. deep, with an internal

diameter of 8 cm. This box is similar in appearance to those used in aneroid barometers. Three-quarters of the space inside is filled up with prepared carbon granules. Through each end of the box passes a small carbon cylinder, insulated from the metal case, and making contact with the carbon inside. These carbon cylinders are connected to the telephone circuit. With this type of microphone no induction coil is used.

The following experiments were then made:—

A beam of sunlight was reflected from a plane mirror, placed outside a window, through a circular aperture 10 cm. diameter. The beam of light then passed through a biconvex lens placed at a distance of 8 metres from the window; the diameter of the lens being 10 cm., and its focal length 22 cm. The spot of light, being really the sun's image, was focused on the microphone.

A cardboard disc with eight equidistant holes in it was mounted near the window, and so arranged that on being rotated by means of a pedal the beam of light was rendered intermittent.

The author calls this disc the interruptor, which was placed as far away from the microphone as possible, in order to diminish all sounds in its vicinity.

A further precaution was taken, and the microphone was surrounded by a well-padded box. If the interruptor be rotated slowly, distinct noises will be heard in the telephone, corresponding to the number of times that the beam of light is cut off. On increasing the speed of the disc the intensity of the noise diminishes, and at a certain speed entirely disappears. It was hoped that at this critical speed a distinct note would be heard, but this was not realised with the type of transmitter in use.

The sounds produced in the telephone are dependent on the action of the thermal rays on the microphone.

On coating the surface of the microphone with lampblack, the sounds were greatly increased. On the other hand, when the beam of light was passed through a solution of alum, or a layer of water, the sounds altogether disappeared.

Experiments were made to prove that the action on the microphone is due to vibrations set up in the case, due to heating and cooling, and that these vibrations are then transmitted to the carbon granules.

A Hunning's transmitter was next used, with which very marked results were obtained, due to the great sensitiveness of this type of transmitter.

When the disc was rotated to give 100 interruptions per second, the noises in the telephone disappeared, and a distinct note was heard; the note being altered by varying the speed of the disc.

The author has not yet determined which of the thermal waves give the best results, but he is of opinion that the red and ultra-red waves do so.

In the above experiments it is necessary to carefully focus the sun's image, and to work when it is at its maximum brilliancy. It is also advisable not to allow the microphone to get hot, or its sensitiveness is diminished.

CLASSIFIED LIST OF ARTICLES

RELATING TO

ELECTRICITY AND MAGNETISM

Appearing in some of the principal Technical Journals during the Months of FEBRUARY and MARCH, 1894.

S. denotes a series of articles. I. denotes fully illustrated.

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G. Claude—Hydraulic Analogies as an Aid to Comprehension of Electric Phenomena.—*Lum. El.*, vol. 51, No. 10, p. 459, No. 11, p. 513 (S. I.).

L. Boltzmann—On the Relation of Equipotential Lines and Magnetic Lines of Force.—*W. A.*, vol. 51, No. 3, p. 550.

K. Noack—On the Experimental Foundations of Ohm's and Kirchhoff's Laws.—*Beibl.*, vol. 18, No. 3, p. 363.

G. M. Minchin—Calculation of the Coefficient of Self-Induction of a Circular Current of given Aperture and Cross Section.—*Phil. Mag.*, vol. 37, No. 226, p. 300.

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E. Semmola—Production of a Sound in a Microphone under the Influence of Intermittent Thermal Radiation.—*C. R.*, vol. 118, No. 10, p. 525.

L. HOULLEVIGUE—On the Variations of the Peltier Effect produced by Magnetisation.—*C. R.*, vol. 118, No. 12, p. 629.

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E. SOLVAY—The Function of Electricity in the Phenomena of Animal Life.—*Ibid.*, No. 11, p. 541, No. 12, p. 598.

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E. M. SCHNEIDER—A Simple Lecture Experiment showing Electric Fields.—*Ibid.*, p. 361.

F. NIEMÖLLER—On the Laws of Conductivity of Liquids.—*Ibid.*, p. 364.

A. DE HEMPTINNE—The Conductivity of Flames and Gases.—*Ibid.*, p. 388.

C. HEIM—Mean European Time and our Electricity Works.—*E. T. Z.*, 1894, No. 9, p. 119.

H. MÜLLER—Switching Apparatus for Inductive Circuits.—*E. T. Z.*, 1894, No. 10, p. 136.

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[Presented by W. H. Blakeney, Member.]

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[Presented by the Secretary of State for India.]

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[Presented by Baudry et Cie.]

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JOURNAL

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Founded 1871. *Incorporated* 1883.

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The Two Hundred and Sixty-third Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, April 12th, 1894—Mr. R. E. CROMPTON, M. Inst. C.E., Vice-President, in the Chair.

The minutes of the Ordinary General Meeting held on March 29th were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Alfred Samuel Lloyd.

From the class of Students to that of Associates—

Arthur George Bird. | Arthur B. Rigby.
Walter E. Toy.

Mr. Charles Bright and Mr. W. R. Rawlings were appointed scrutineers of the ballot for new members.

Donations to the Library were announced as having been received since the last meeting from Messrs. Baudry et Cie., Mr. A. Blondel, Mr. G. Sartori; Lord Kelvin, Past-President; Mr. T. C. Martin, Foreign Member; Sir H. Mance, Vice-President; and Sir Charles Todd, Member; to all of whom the thanks of the meeting were unanimously accorded.

The CHAIRMAN: Professor Ayrton has an addition to make to the paper by himself and Mr. Mather read at our last meeting on "A Universal Shunt Box for Galvanometers." It is proposed before the discussion proceeds further that Professor Ayrton should read that addition.

Professor Ayrton

Professor W. E. AYRTON, F.R.S.: Since this paper was read on the last occasion, there have, of course, been criticisms on the new method we propose for shunting. One of the criticisms, if you will allow me to say so, is based really on a wrong conception of the way in which shunts are used. The objection that has been made is this: In Fig. 4 of our paper—which, perhaps, best illustrates the method we propose—the largest current which passes through the galvanometer is less than the current in the mains. When you move the main M_2 to the dotted position (Fig. 4), the current which now passes through the galvanometer is exactly 1-10th of that which previously passed, but not 1-10th of the current in the main itself. It was, therefore, contended that the method would not have any very great application. This objection, however, would only be a valid one if a Thomson reflecting galvanometer was an instrument of *invariable sensibility*, and was provided with a direct-reading scale graduated in microamperes; whereas, as you all know perfectly well, owing to the change of the astaticism of the needles from day to day, the change of the position of the controlling magnet and of iron in the neighbourhood, "the constant" of a Thomson galvanometer has to be taken whenever you desire to use the instrument. Now it is just as easy to take "the constant" with a resistance r permanently shunting the galvanometer as when there is no such shunt.

Let me take an example—for there is nothing like an example

to illustrate one's meaning. There were two currents that I wanted to compare: one was a current of 1 microampere, and the other was a current, x, the value of which I desired to ascertain. We will consider the use of our universal shunt box (Figs. 7 and 8 in the accompanying table) first. Professor Ayrton.

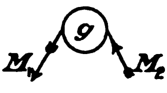

FIG. 5.

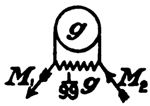

FIG. 6.

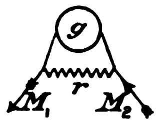

FIG. 7.

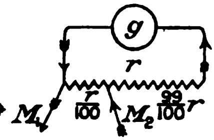

FIG. 8.

COMPARISON OF CURRENTS.				COMPARISON OF CAPACITIES.						
				CONTROLLING MAGNET DOWN.			CONTROLLING MAGNET UP.			
Current in Main.	Deflection.	Apparent Ratio of 2nd Current to 1st.	True Ratio of 2nd Current to 1st.	Capacity of Condenser.	Swing.	Apparent Ratio of 2nd Capacity to 1st.	Capacity of Condenser.	Swing.	Apparent Ratio of 2nd Capacity to 1st.	True Ratio of 2nd Capacity to 1st.
1 microampere	590·6	99·63	100·0	⅓ of microfarad	637·0	99·38	⅓ of microfarad	629·1	91·87	103·45
x	588·4			x	633·0		x	578·1		
1 microampere	536·7	99·99	100·0	⅓ of microfarad	575·5	103·5	⅓ of microfarad	559·0	104·0	103·45
x	526·6			x	595·5		x	581·3		

When the microampere was flowing through the main (Fig. 7), the deflection was 536·7. Next we sent the current x, the value of which we desired to determine, through the mains; and, as the current x was much larger than the first current, we changed the main wire from the end of r to a point situated at 1-100th r from the left-hand end (Fig. 8), and obtained a deflection 536·6: then we knew that the ratio of the second current to the first was $100 \times \frac{536 \cdot 6}{536 \cdot 7}$, or 99·99, so that the second current was 99·99 microamperes. As a matter of fact, the true relationship of these two currents was exactly 100; that is to say, the circuits were so arranged that the second one, x, was exactly 100 times the first current, quite independently of the accuracy or inaccuracy of the resistances in our shunt box. Hence, as the universal shunt box was not employed at all in arranging these two currents, the ratio

Professor Ayrton.

coming out as 99·99 constituted a proof of the accuracy obtainable by using our new form of shunt box.

Next let us consider the ordinary method. In the ordinary method of comparing these two currents, we sent the one microampere through the galvanometer without the galvanometer being shunted at all (Fig. 5), and we obtained a deflection 590·6. Next, the galvanometer was shunted with the 1-99th shunt supplied with the galvanometer—that is, with a shunt which was supposed to have a resistance the 1-99th of the resistance of the galvanometer—and the deflection then obtained was 588·4. Hence the ratio of the second current to the first was $100 \times \frac{588 \cdot 4}{590 \cdot 6}$, or the current x was 99·63 microamperes.

Now this specimen of the ordinary form of shunt that we employed is wound with copper like the galvanometer itself, and was very carefully adjusted by a good instrument maker when originally constructed at the same time as the galvanometer. Further, it is screwed down close to the galvanometer, and has been in the fixed position close to the galvanometer not only for months, but I may say for years, in a basement room where the temperature does not vary very much; still, the test of the ratio of two currents made with this galvanometer, using the shunts supplied with it, was not so accurate as the comparison of the same two currents when using our shunt box, although this new shunt box was constructed without any reference whatever to this particular galvanometer—in fact, the coils were wound by a person who had neither seen the galvanometer nor knew anything about its resistance.

It is important, also, to notice that the apparent ratio of these two currents, as obtained with the ordinary shunt, being 99·63, while the true ratio was exactly 100, could not possibly have been due to any want of proportionality between the deflection of the galvanometer and the current producing it. For, as the current x was made exactly 100 times the first current, it follows that, if the resistance of the shunt had been exactly 1-99th of that of the galvanometer, the two deflections must have been equal, *whatever was the law connecting the deflection of the galvanometer and the*

Professor Ayrton.

current. Indeed, it was to avoid any error being introduced by the calibration of the galvanometer not being a straight line that we employed two currents, one of them exactly 100 times the other, and the 1-99th shunt.

The error of 0·4 per cent. in the comparison of these currents gives an idea of the sort of error that occurs even under the *most favourable* conditions when using an ordinary shunt box. Had, however, the galvanometer been usually kept in one room, and the ordinary shunt box in another, before the test was made, it is probable that the error would have been much greater than 0·4 per cent., no matter how accurately the resistance of the shunt box had been originally adjusted by the maker when it was constructed.

Let us go a step further. All the uses of an ordinary reflecting galvanometer are either to measure two currents or to measure two rushes of electricity. In comparing two resistances, or two E.M.F.'s, or whatever the galvanometer may be used for, the deflections either measure two currents or two rushes of electricity in the mains. Let us, then, consider the comparison of the capacities of two condensers, and in this case I will take the ordinary method first.

A condenser of one-third microfarad capacity first was charged and discharged through the galvanometer unshunted (Fig. 5), and an instantaneous deflection of 637 divisions was observed. Next, a larger condenser of capacity x was charged with the same E.M.F., and discharged through the same galvanometer shunted with the ordinary 1-99th shunt (Fig. 6), and an instantaneous deflection of 633 scale divisions was obtained. The apparent ratio of the second capacity to the first was therefore $100 \times \frac{633}{637}$, or 99·38. As a matter of fact, the second capacity was actually greater than 100 times the first, the true ratio being 103·45.

Now it is stated in the criticism I am referring to that ordinary shunts have a "definite damping constant." I am not quite sure what that means; but if it means that the same correction has to be applied in all cases, it is wrong. For after moving the controlling magnet from the position it had at first into a new position further up, so as to diminish the controlling

Professor Ayrton.

force, the same experiments were repeated with the same condensers, using the same ordinary 1-99th shunt as before: then the instantaneous deflections were 629·1 and 578·1, as given in the table. Consequently the apparent ratio of the capacities was 91·87. Not only, then, are both these results wrong, but they are not wrong by anything like the same percentages. The first ratio, being 99·38 instead of 103·45, is about 4 per cent. wrong; while the second ratio of the capacities, 91·87, obtained with the new position of the controlling magnet, is about 12 per cent. wrong.

Now, using our shunt—which, as I say, was not constructed for this particular galvanometer, nor were the coils wound by a person who had even seen the galvanometer, or knew anything about its resistance—the same two condensers were compared first with the controlling magnets down, and the actual instantaneous deflections were 575·5 and 595·3, giving a ratio of the second capacity to the first equal to $100 \times \frac{595 \cdot 3}{575 \cdot 5}$, or 103·5; next with the controlling magnet up, when the swings were 559 and 581·3, corresponding with a ratio of the second capacity to the first equal to $100 \times \frac{581 \cdot 3}{559}$, or 104, which is practically the same as the former value, 103·5.

Therefore these two results are not only practically the same but they are both right, and no correction whatever has to be applied. You have, therefore, a much more easy and accurate method of comparing two capacities with our shunt than with the ordinary shunt.

Mr. Hockin's mathematical analysis clearly showed years ago that the error in comparing capacities with an ordinary shunt depended upon the position of the controlling magnet, and therefore the correction which had to be applied with one position of the controlling magnet was quite different from the correction necessary when the controlling magnet had a different position. But I doubt whether this fact is generally recognised.

This great difference between the apparent ratio of the capacities obtained with the ordinary shunt and the true ratio did

not arise from the galvanometer that we employed being unsuited for ballistic work, for, as a matter of fact, it was specially constructed for use as a ballistic galvanometer, and had a logarithmic decrement of only 0·053 when we used it—a value which, as those who are familiar with ballistic galvanometers will realise, is not at all large for a galvanometer employed for the relative comparison of capacities. The great discrepancy arose from the great damping that was introduced on applying the ordinary 1-99th shunt, and which, unless a special correction were applied (depending on the position of the controlling magnet), led to an error of about 4 per cent. even in the most favourable case, when the controlling magnet was in its lowest possible position and produced its greatest controlling force. Professor Ayrton.

I think, then, we are justified in saying that the proposed method of constructing a shunt box is more *universal*, and gives much more accurate results than a shunt which is specially prepared for a particular galvanometer.

Now how about the price? Well, we have obtained an estimate of the price for making shunts, and the results are very interesting. The following is the rough specification we sent out in order to obtain estimates :—

" *Four Separate Estimates to be Supplied for Constructing*

" No. 1.—Ordinary shunt box for a galvanometer of 1,000 " ohms, the shunt consisting of three coils of 1·111 " ohms, 10·10 ohms, and 100·1 ohms respectively.

" No. 2.—A shunt box containing three coils of 10 ohms, " 90 ohms, and 900 ohms respectively.

" No. 3.—A shunt box containing three coils of 100 ohms, " 900 ohms, and 9,000 ohms respectively.

" No. 4.—A shunt box containing three coils of 1,000 ohms, " 9,000 ohms, and 90,000 ohms respectively.

" Each coil to be adjusted in each case to an accuracy of 1-10th " per cent.

" All the coils to be of the same material—German silver, " platinoid, manganin, or whatever wire you prefer; name of wire " to be stated.

" Each box to be complete, with two plugs, similar finish, &c."

Professor Ayrton. And the following are the quotations:—For constructing the shunt boxes Nos. 1 and 4 the price is £4 5s. each, and for Nos. 2 and 3 £3 15s. each; so that a universal shunt box with the total resistance of 100,000 ohms costs no more than an ordinary shunt box for a galvanometer of only 1,000 ohms resistance, while a universal shunt box with a total resistance of 10,000 ohms costs actually less, the difference in price arising from the extra cost of the wire being more than compensated for by the saving of labour in adjustment.

Consequently, as a 10,000-ohm universal shunt is quite high enough for a galvanometer of about 1,000 ohms resistance, we may say that the new method of construction not only enables the same shunt box to be used with galvanometers of very different resistances, and with an accuracy greater than can be obtained with a shunt box specially constructed in the ordinary way for each particular galvanometer, but actually costs less than such a special shunt box.

Mr. Bright. Mr. CHARLES BRIGHT: There is one disadvantage which occurs in Messrs. Ayrton and Mather's arrangement of galvanometer shunts, and that is, the feature of having a certain fixed resistance permanently in parallel with the galvanometer. By this means the advantage attained by using a very sensitive Thomson reflecting galvanometer must to a great extent be lost. In practice it is often important to obtain the most sensitive astatic suspension possible when testing very high resistances, whether in the form of the dielectric resistance of quite short lengths of experimental core or otherwise. In such a case it is highly desirable to have not only an appreciable deflection for purposes of accuracy in results—and, for the same reason, as near as possible to the same part of the scale as obtained with the "constant," or known, resistance—but also for the purpose of securing a means of observing what sort of electrification (polarisation or absorption) is taking place, whether regular in its rate of decrease or otherwise. If this highly sensitive system is then even lightly shunted, this object must be to a great extent defeated. Such tests are naturally of daily occurrence, both at cable works and experimental laboratories; and the galvanometer is, of course, always used without any shunt whatever where possible.

[*Communicated.*]—It is only in comparatively rough tests that shunts with resistances bearing certain known fixed proportions to the resistance of the particular galvanometer in use are ever employed. The custom has been to use an ordinary box of variable resistances, and from this insert whatever shunt is required to give the desired deflection, afterwards applying its particular multiplying power. The "universal shunt," however, which Professor Ayrton has brought before us appears in this connection to have a great "field" of usefulness in that, whatever its resistance be, it can be used with a galvanometer of any resistance and yet serve the purposes of a shunt without any calculations, and without even a *knowledge* of the resistance of the galvanometer being necessary. Mr. Bright.

Major Cardew's method of using an electrometer for testing very high resistances, such as the dielectric of samples of covered wire, is applicable for tests in which only a rough idea of the resistance is required. Being a "difference of potential" test only, by this method, however, the electrification and general behaviour of the material under a given E.M.F. cannot be observed, and therefore it is not so *searching* a test as the ordinary deflection method by the Thomson galvanometer.

Professor AYRTON: Mr. Bright is perfectly correct. In the case where the current to be measured is so extremely small that to detect it at all borders on the limits of the possible, it is certainly better to have no shunt at all to your galvanometer, or to make the value of r very large indeed. If you use, for example, a universal shunt having a resistance of 100,000 ohms, that will be pretty large compared with the resistance of the galvanometer itself, which, say, is 3,000 or 4,000 ohms; and in that case the maximum deflection would only be diminished by 3 or 4 per cent. by having the galvanometer permanently shunted with 100,000 ohms. Still, you are quite right: if the current is so exceedingly small that you can hardly detect it, you had better remove the shunt altogether. That, however, is very exceptional. With the delicate galvanometers of the present day, and using a fair number of cells, in testing the insulation of a condenser or the resistance of a piece of gutta-percha cable, you are generally not measuring currents bordering on the limits of the power of the galvanometer; Professor Ayrton.

Professor Ayrton.

and in that case, if the resistance r be fairly high compared with that of the galvanometer, then I do not see any objection whatever to having your galvanometer permanently shunted by a resistance r.

Mr. Crompton.

The CHAIRMAN: We will now resume the discussion on the paper by Professor Ayrton and Mr. Whitehead on "The Best "Resistance for the Receiving Instrument on a Leaky Telegraph "Line."

Mr. Granville.

Mr. W. P. GRANVILLE: Professor Ayrton and Mr. Whitehead at our last meeting laid down the following rule: That the best resistance for a receiving instrument should equal that of the line as measured at that end, with the distant end to earth. May I suggest the following slight addition? The measurement to be made with a duration of contact approximately equal to the duration of contact used in signalling. This is specially important in the case of submarine cables, and on land lines if the speed of working is great, for it is clear that what we want to know is the combined resistance, not as measured after one minute, but as measured after a small fraction of a second, so as to represent the signalling conditions.

In submarine cables the dielectric resistance increases very rapidly during the first minute of contact with the battery; so that it is evident that at the first moment of contact, as in signalling, the dielectric resistance may be even less than that of the conductor. It seems, therefore, that some such addition as that suggested might be of use.

Professor Hughes.

Professor D. E. HUGHES: I should like to express my great pleasure in seeing a telegraph paper here. It is so long since we have had one that it is quite a treat to see one again. I have already told my friend Professor Ayrton that I do not quite like the title of his paper, "The Best Resistance for the Receiving "Instrument on a Leaky Telegraph Line." I think it might mislead anyone who does not understand what that really means. The best resistance evidently would be none at all. What we want is conductivity; we want the least resistance possible in an electro-magnet, provided we can get it to do what we want. I think the test that has been made by Professor Ayrton has been

Professor Hughes.

made in the steady period of the current. All tests with electro-magnets should be made under the conditions for which they are used. I made a special study of this many years ago for my printing instrument in 1860. The law then was considered general; in fact, up to this date, the law was that the resistance of the receiving magnet should be equal to that of the line. My first magnets were so constructed; but I always doubted this law, and I made a special course of experiments to see whether this law was correct for telegraph lines. I found very soon that the self-induction of the magnet induced an apparent resistance, and if I worked it by rapid contacts the resistance of the magnet would become enormously great. I will not go through these long series of experiments with an electro-magnet designed for a line of 500 miles. The result, however, is that I have found it best under all conditions of losses to have the electro-magnet one-fourth of the resistance of the line. If the resistance of the line is very low, through great losses, we can do with still less—1-16th. The electro-magnets for my telegraph instrument were constructed in accordance with this. For a line of 1,000 miles I had 1,250 ohms resistance; and this was so arranged that we could pass the current through the two coils in series or parallel, so that they could use it as 1,250 ohms or 312·5 only. There were very rare conditions in which the 312 ohms resistance would not act just as well as the 1,250. With the resistance of 5,000 ohms electro-magnet for a 5,000-ohm line, the resistance of the magnet was entirely too great; and if we add the resistance induced by self-induction of the magnet, the resistance became very great. I am perfectly convinced that in all receiving instruments throughout Europe the resistance of the electro-magnets of telegraph relays and instruments are all too high. The principle which I have adopted in my instrument, and which I have always tried to follow, is to reduce the resistance as much as possible. I have experimented on lines of 1,000 miles. These experiments were not laboratory experiments, but experiments which have been watched for months and months to see the effects on each line. I have never met a case where a large resistance, equal to that of the line, would work as well as an

Professor Hughes.

electro-magnet whose resistance was one-fourth of the line. I think, therefore, it is a great mistake to have too high a resistance in the magnet. The tendency of Professor Ayrton's results would be to lower the resistance of the magnet, and would be following very much the same course as I have done; but we must not construct electro-magnets altogether for a bad line. There are times, fortunately, when the lines are good. It used to be very rare, but now it is the general thing. In the olden times we were very glad if we could get through any signals at all, as the losses were so great through want of insulation. When we design a telegraph instrument electro-magnet we cannot state any given line for use for the electro-magnet, as they are all constructed on a given model, and those models are used indifferently all over the country. One works at 500 miles, another at 300, and another at 200, and one even on a very short circuit. The maker never knows where his instruments go, and therefore the maker or the inventor must try to find out what is the average length of the line that the instrument is to be used on, as well as the average condition of the line. He must take all these things into consideration, and he must design his electro-magnet to meet the average condition of the line. If it will work perfect in a medium condition, it will probably go when it is bad, and it will be sure to go when it is good; if designed only for a good line, it will certainly not go when it is bad. Looking at all these points, as I have already said, I found the low resistance, within a certain limit, 312 ohms for a 1,000-mile line, to be the best; provided the electro-magnet is well designed, polarised by a permanent magnet, sensitive to the smallest current, with a long range of adjustment, and its armature very light, so as to have as little inertia as possible. On the line we not only are troubled with losses alone; and if we experiment with a fictive line in a laboratory, making false losses alone, we do not get all the conditions of an actual line, for we have on lines mutual induction, induced currents, earth currents, &c. Then sometimes we have a remarkable state of affairs, which I have noticed only in Southern countries. In England we have losses, induction, and earth currents; but when you get to Spain and Turkey, and hot

countries, even if the line is perfectly insulated, and you are using rapid instruments, there will be a sudden jerk, or sudden current—not an earth current: it is not prolonged, but a rapid single momentary current every few minutes, sufficient to reverse or greatly weaken the signal you are sending. These are caused by atmospheric influences. This momentary current is so short and rapid that if you put a steady galvanometer on the line you do not observe any fluctuation, but all rapid signalling is stopped or signals falsified. It has been noticed by M. Bandot in Paris, as well as by myself, that all rapid instruments suffer from these conditions. Therefore when we design an electro-magnet we have to take into account an enormous number of conditions. One of the earliest conditions we used to work upon in the laboratory was to spread a great many losses over a fictive line, as Professor Ayrton has done, and I came very much to the same conclusion that he has. I would ask Professor Ayrton what resistance he would choose for a 5,000-ohm line. The paper is not very clear as regards that. I think, however, if he were to go over 312 ohms he would make it a little too high. I have to congratulate Professor Ayrton on giving us this paper, and bringing the subject of telegraphing back again, thereby giving us the opportunity of discussing this subject. Professor Hughes.

Professor AYRTON (in reply): I am sorry, after the telegraphists have so often said in this room that their interests were neglected, and that a telegraphic paper was never read, that this paper has not elicited more remarks. If the telegraphists would only come and say that the paper was wrong, it would at any rate show that they still took an interest in the meetings of this Society. I certainly did hope that this paper might have attracted some of the telegraph section of our Society. Professor Ayrton.

Of course, in presenting this paper, Mr. Whitehead and I do not wish it to be supposed that after a long practice of telegraphy people have not arrived at some sort of notion as to what is the best resistance to give to the receiving instruments. Indeed, the late Mr. Schwendler, 22 years ago, when I was his assistant, published a rule that the resistance of a telegraph relay should be equal to five-eighths of the *true* resistance of the line wire.

Professor Ayrton.

That did not mean the resistance of the line tested in the way we have described in our paper, but the *true* resistance of the wire neglecting all leakage. That rule was obtained by taking a mean of what would be the best resistance of the relay, first, if the line were perfectly insulated, and, secondly, if there were a dead earth in the middle of it. From those two comparatively easy considerations Mr. Schwendler arrived at the conclusion that the best resistance of a telegraph relay should be five-eighths of the true wire resistance. His rule would give the same result as we have arrived at in certain cases; but when a line is badly insulated, our conclusion will lead to a less resistance being adopted for the relay than five-eighths of the true wire resistance of the line neglecting leakage. I am not aware, however, that this problem has ever before been examined mathematically in a perfectly general form, so that the solution would be applicable to any line with any distribution of leakage along it. A step was made some 18 months ago towards the solution of this by Mr. Everett, an associate of this Institution, then a student of mine. It was not, however, until last autumn that Mr. Whitehead and I saw how to attack this problem in a perfectly general way; and it is this general mathematical solution, and the extremely easy rule that it leads to, that forms the subject of this paper. As Professor Hughes has remarked, the title is perhaps a little misleading. It might appear, perhaps, as if a telegraph instrument would be better if it had a certain resistance than if its coils were wound with wire of infinite conductivity. Of course, what is meant is that while resistance *per se* is a bad thing, a number of convolutions in an electro-magnet is a good thing. As, however, with any material with which we are acquainted you cannot obtain convolutions without resistance, there is a certain resistance which is best for a galvanometer or a telegraph receiving instrument depending on the particular conditions existing. And, as we have shown, the best resistance for a receiving instrument is in all cases equal to the apparent resistance of the line as tested from the receiving end and put to earth at the sending end.

It has been asked, What is the good of obtaining a rule for the

resistance of the receiving instrument which depends on the insulation of the line; for the insulation of the line changes from day to day, and you cannot be perpetually altering the resistance of your receiving instruments? The answer is, of course, this: When the line is in good order and the insulation is high, there is no difficulty in signalling, and it is only when the insulation is low—because, for example, it is raining all along the line—that trouble occurs. Therefore I think that it is best to adapt the resistance of the receiving instrument to suit the line in its most leaky normal condition—that is, when the insulation is lowest without there existing any temporary fault that can be removed. Professor Ayrton.

Professor Hughes asked what resistance I should give the instrument if the resistance of the line was 5,000 ohms. If the wire itself had 5,000 ohms, I cannot answer the question, because the answer depends on the insulation also.

Professor HUGHES: 2,000; the wire is 5,000, but the loss makes it 2,000.

Professor AYRTON: I think in that case you would find a resistance a good deal higher than 300 ohms would be good for the relay. That certainly is the conclusion we came to experimentally in India. The officials are intelligent there, and they do not put instruments happy-go-lucky on the lines. They make the resistance of the receiving instrument suit a particular line, and they do not construct instruments of the same average resistance and send them out, so that a line 50 miles long has the same type of instrument as a line working direct from Calcutta to Bombay, which is as far as from here to St. Petersburg: in that case the relay has several thousands of ohms. In 1872 we found it better to increase the resistance, for we were then suffering in India from the relays having much too low resistance; but Professor Hughes appears to have been suffering from too high a resistance. I think, perhaps, that the difficulty met with in hot countries, to which Professor Hughes has alluded, may arise from the discharge of the line acting as condenser. Twenty years ago we had a great deal of trouble in India from that same cause. If the line is long and the insulation is high, the wire becomes

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a very fair condenser, and you get a return signal from the discharge of the line.

Professor HUGHES: It was during continuous work. There were interruptions every few minutes or so.

Professor AYRTON: If the trouble had arisen from the capacity effects of the line, it would have occurred more frequently than every few minutes. We found that this discharge from the line interfered with rapid signalling on the long lines in India, which, of course, like Spain, is a hot country; but this difficulty was overcome by having a resistance permanently shunting the relay.

The following papers were then read:—

TRANSPARENT CONDUCTING SCREENS FOR ELECTRIC AND OTHER APPARATUS.

By W. E. AYRTON, F.R.S., Past-President, and T. MATHER, Associate.

Professor Ayrton and Mr. Mather.

It is well known that electrostatic instruments require to be screened from outside electric disturbance, in order that their indications may be correct; but it is not so generally recognised that instruments intended to measure small forces, such as certain types of *electro-magnetic* voltmeters, delicate vacuum gauges, &c., are liable to give wrong readings from an electric attraction being exerted on the pointer, such as is produced by the glass cover when it is touched or cleaned.

There is on the table here a well-known type of gravity *electro-magnetic* voltmeter, which may be found on the switchboards of many English and Continental electric light stations. At the present moment its terminals are not connected with the electric light mains of the building, so that it should indicate zero pressure. Let me, however, but stroke the right-hand side of the glass cover with my finger, and the pointer, as you see, at once turns to 80 volts or more. Conversely, let the terminals of the voltmeter be connected with the electric light mains: the pointer should point to about 100 volts, for that, as you know, is the pressure supplied by the Westminster Company. The

voltmeter appears to be indicating correctly, but, on stroking the left-hand side of the glass cover, the pressure, as read by the instrument, appears to suddenly fall to some 40 volts. And a similar effect is produced if a piece of wash-leather or dry waste be used in place of the finger. Professor Ayrton and Mr. Mather.

If, then, it is possible to cause this instrument to indicate at will 60 or 80 volts too high or too low, how impossible must it be or feel sure that the glass cover—which is, of course, maintained in a dry condition in a hot engine room—has not been electrified by some accidental touch of the coat sleeve sufficiently to cause an error of 3 or 4 per cent. in the reading of this voltmeter!

We find that it is not merely with this particular type of voltmeter that an error can be produced by stroking or rubbing the glass cover, for other electro-magnetic instruments that we have tried can also have their pointers deflected in the same way, but not to the same extent.

Nor, of course, is this source of error in any way connected with a voltmeter being an instrument constructed to measure an electrical magnitude, for it would equally exist if the glass were clean and dry and the controlling force remained of the same magnitude, no matter what was the quantity the instrument was constructed to measure. For example, on the table there is a vacuum gauge the wheel-sector-pinion of which has been replaced with an Ayrton-Perry magnifying spring. This gauge is, no doubt, very sensitive, for you observe that the pointer moves even when I produce an extremely slight diminution of pressure by rotating the short length of india-rubber tube as slowly as I can; the change of pressure on pinching the tube, or even on dropping it, is indicated by the pointer. On the other hand, the pointer is of glass, and therefore is not suitable for being acted on by an electrostatic force; still, a stroke on the glass cover, as you see, causes the pointer to deflect through several degrees.

It has been known for a long time that it is possible to screen an instrument from such outside electrostatic disturbances by surrounding it with a metallic cage composed of wire or of strips of tinfoil. Such a method of screening, however, has the great

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disadvantage that it renders it difficult to observe the exact position of the pointer from a distance, for the wires or strips of tinfoil cover up the pointer more or less. We therefore thought of placing the pointer underneath the metallic dial of our electrostatic voltmeters, and of only allowing the tip to project through a slot in the dial plate. But this method we abandoned on trying it eighteen months ago, for to make the screening good the visible part of the pointer must be reduced to a spot, and the exact position of this spot we found less easy to read at a distance of several feet than that of a long black line, which is the appearance of a pointer when it is visible along its whole length. This method of screening has, however, we understand, been recently adopted by a firm of instrument makers.

We next considered whether it was not possible to make a perfectly transparent conducting screen, so that, while the electrostatic screening of the pointer should be practically perfect, the pointer and dial should be as easily seen as if the screen were not present. Our first idea was to make the glass cover double, and to insert between the two sheets of glass a layer of clear conducting liquid. Fearing, however, trouble from leakage of the liquid, or from the liquid becoming gradually turbid and giving the dial a dirty appearance, we turned our attention to depositing films of solid matter on the inside of the glass cover, or shade, of sufficient thinness to be practically transparent, but with the solid particles near enough together to be conducting. We tried smoke, silver deposited in layers of various thicknesses, mercury vaporised and deposited, sal-ammoniac vaporised and deposited, &c., but we were quite unable to obtain in this way both transparency and electric conduction.

After a conversation with Professor Boys, when discussing the problem that we were then engaged in solving, we commenced experimenting on varnishes, with the view of arriving at a varnish which should be as hard and as transparent as *clear* shellac, but which, instead of being an insulator like shellac, should be a sufficiently good conductor to allow of the instantaneous production of an induced electric charge to balance the electrostatic action of any outside body. Glass plates were coated with gum,

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with coaguline, with the gelatinous electrolyte used in accumulators (composed of sodium silicate and dilute sulphuric acid), with isinglass dissolved in acetic acid, with gelatine dissolved in acetic acid, with isinglass dissolved in a mixture of acetic and sulphuric acids, and with gelatine dissolved in the same mixture. After much experimenting, we arrived at the following two methods of coating a glass cover, or shade, which gives perfectly satisfactory results :—

No. 1.—Dissolve ¼ ounce of transparent gelatine in 1 ounce of glacial acetic acid by heating them together in a water bath at 100° C. To this solution add half the volume of dilute sulphuric acid which has been prepared by mixing 1 part of strong acid with 8 of distilled water by volume, and apply the mixture while still warm to the glass shade, which should be previously polished and be warm. When this film has become very nearly hard, apply over it a coating of Griffith's anti-sulphuric enamel.

Method No. 2.—Thin the gelatine solution, prepared in the manner previously described, by the addition of acetic acid (say 2 volumes of acid to 1 of the solution), and, after polishing the glass, float this thinned solution over the glass cold. Drive off the excess of acetic acid by warming, allow the glass to cool, and repeat the floating process, say, twice. Thin the anti-sulphuric enamel by the addition of ether, and float it over the gelatine layer applied as just described. Expel the ether by heating, and apply a second layer of this thinned anti-sulphuric enamel.

With experience, such as Messrs. Elliott and Messrs. Paul have at length acquired after much practice, a layer can be applied, either according to method No. 1 or No. 2, so that, when finished, it is quite hard to the touch, and so transparent that it is only by looking at the glass plate obliquely that the presence of the varnish can be detected. It is also so conducting that when a P.D. of several thousand volts, alternating with a frequency of 200*, is set up between the needle and inductors of

* The frequency is mentioned because a film might be a sufficiently good conductor to screen the action of a steady electric charge, and yet not conduct nearly well enough to prevent the attraction between two oppositely electrified bodies whose charges were both reversed *simultaneously* 400 times a second.

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one of our electrostatic voltmeters, the pointer, which is metalically part of the needle, is not visibly attracted by a metallic rod held just outside the glass close to the pointer, this metallic rod being electrically connected with the stationary inductors.

Without experience, however, it is somewhat difficult to apply the coating so that it is not either cloudy, or a comparatively poor electrostatic screen, or both.

This second electro-magnetic voltmeter—which, like the former, has been kindly lent us by Mr. Barley, of the Knightsbridge electric light central station—looks exactly like the other one, and, indeed, behaved exactly like the other one when we received it. It has, however, had a layer of our transparent varnish applied on the inner side of the glass subsequently, and you will find that you may rub the glass as much as you like, or even hold a rubbed stick of ebonite near it, without producing any effect on the pointer.

Again, these two clear glass shades, belonging to gold-leaf electroscopes, are one of them coated with our varnish, and the other not. Which is the uncoated one is at once apparent from the alteration produced in the deflection of the gold leaves when I approach a stick of rubbed ebonite near the lower part of the glass shade of the uncoated one, for no such change in the deflection is produced, as you see, when the ebonite rod is brought near the glass shade, which is protected by a layer of this varnish applied on the inside.

AN ASTATIC STATION VOLTMETER.

By W. E. Ayrton, F.R.S., Past-President, and T. Mather, Associate.

The rapid development of electric lighting generating stations during the past three years has resulted in a greatly increased perfection in the regulation of the pressure, and consequently has created a need for measuring instruments of much greater precision than was previously required. At the same time, the powerful dynamos now employed, and the large currents, that flow

through the mains on the switch-boards at these generating stations, has greatly increased the disturbing influences to which electro-magnetic measuring instruments are subjected. Consequently, it is not to be wondered at that voltmeters and ammeters which answered fairly when the output of the stations was small have had to be discarded as being unsuitable for the present requirements. Professor Ayrton and Mr Mather.

The authors have, therefore, been engaged for some time past in developing an electro-magnetic voltmeter to fulfil the following conditions :—

1. Be unaffected by an outside magnetic field, whether uniform or not, and as strong as the disturbing magnetic field on any ordinary central station switch-board.
2. Be unaffected by an outside electrostatic disturbance such as is produced on rubbing the glass front of the instrument.
3. Have no temperature error.
4. Have a high resistance, so as to measure equally accurately the *true* pressure at the end of long thin pilot wires, or in the station itself.
5. Have a scale of large radius, and one very open at the working pressure, so that a small change in the pressure can be detected.
6. Be dead beat.

Condition No. 1 is most easily fulfilled by employing a powerful stationary permanent magnet and a moving coil, for such an arrangement has the great advantage that it cannot indicate a pressure unless a current be actually flowing through the coil; whereas soft iron and other types of voltmeters, when placed in a fairly strong magnetic field, may have the pointer deflected across the scale when no current whatever is passing through the instrument. But it is not sufficient to merely employ one permanent magnet and one moving coil, as is proved by the fact, which is probably not generally known, that the

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very beautiful Weston voltmeter,* in spite of the permanent magnet being strong and the air gaps in which the coil moves being extremely small, indicates slightly differently when put in different positions in a magnetic field even as weak as that of the earth's, the change in the reading being about one-fifth per cent. when the instrument is placed horizontally and turned through an angle of 180 degrees in a horizontal plane. This voltmeter therefore cannot, of course, give constant indications in a varying magnetic field 50 or 100 times as strong as that of the earth's. Now Messrs. Clark & Malpas have found, by experimenting with our portable magnetic field tester, that a field of 20 C.G.S. units, or one rather more than 100 times as large as that due to the earth, is the sort of magnetic disturbance that occasionally occurs on the switch-boards of existing central stations, while fields of six C.G.S. units—that is, 30 times the earth's field—are quite common.

If the coil be wound astatically, and be acted on by two powerful permanent magnets inside the voltmeter, with their poles oppositely directed, good screening can be obtained from a uniform disturbing magnetic field; but errors will be produced if the disturbing field be *non*-uniform, such as is caused by a mass of iron, or by a conductor carrying a current, placed near the voltmeter. We have, therefore, carried this principle of astaticism further by employing *three* permanent magnets and a coil wound in three parts, as shown diagrammatically in Fig. 1,

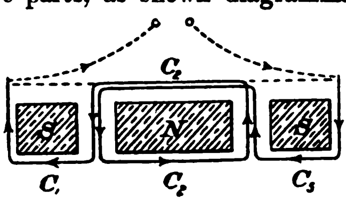

FIG. 1.

* Tests made from month to month of the sensibility of two of the latest form of the Weston voltmeter show also that the sensibility slowly *increases*. This arises, probably, from the permanent magnets having been too much weakened before these instruments were originally calibrated, so that the magnets have *increased* their strength with time. These two instruments now read 1·3 per cent. and 1·7 per cent. too high respectively, after allowing for the fact that the unit P.D. employed in the original calibration was the legal volt, and not the "Board of "Trade" or "International" volt.

the area of the middle coil being double that of either of the end ones; and in this way we have obtained an arrangement which is comparatively unaffected by either a uniform or a non-uniform magnetic disturbance. Professor Ayrton and Mr. Mather.

The moving coil principle also enables conditions 3 and 4 to be fulfilled, for the resistance of this 100-volt instrument is about 7,000 ohms; and as only 3 per cent. of this is composed of copper wire —viz., that wound on the moving triple coil—while 97 per cent. is of manganin wire, indicated by the stationary coil R in Figs. 2 and 3, the temperature error is practically negligible. This high resistance also causes the power required to actuate the voltmeter to be very small, not more than about $1\frac{1}{2}$ watts being absorbed at 100 volts with this voltmeter.

The control is produced by a weight, because this is the method of exercising a controlling force that is least likely to vary, and because the objection to the employment of a gravity control —that the voltmeter cannot be used in any position—is of no importance in the case of a switch-board instrument.

Fig. 2 shows the voltmeter in elevation, while Fig. 3 gives a plan; both figures being drawn partly in section, so that the working parts may be more clearly seen. The triple coil C_1, C_2, C_3 (Fig. 1), turns about the axis C and passes over the poles of the three magnets, M_1, M_2, M_3 (Fig. 3), the direction of the winding being such as to cause the deflecting forces for each portion of the coil to be in the same direction. The current is led up to and away from the coil by very thin flexible silver strips attached to the points of the stationary pieces w, w' (Fig. 3).

Conditions 5 and 6 are satisfied by specially shaping the air gaps, and we find that without sacrificing the quickness of motion of the pointer P too much, we can flatten the calibration curve at the working part of the scale so that 1-100th part of a volt variation in the pressure can be detected.

A bit of the scale, *full size*, is seen in Fig. 4, and, although large and bold, an additional means for indicating whether the pressure is correct or not is provided by means of the index I (Fig. 2). This index can be moved and set at any desired position by turning the milled head H, which actuates a crown

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wheel segment, Q, carried by the ring to which the arm I is attached. This index arm is coloured *black*, while the pointer P and the arrow-head at the lower end of the index arm are coloured

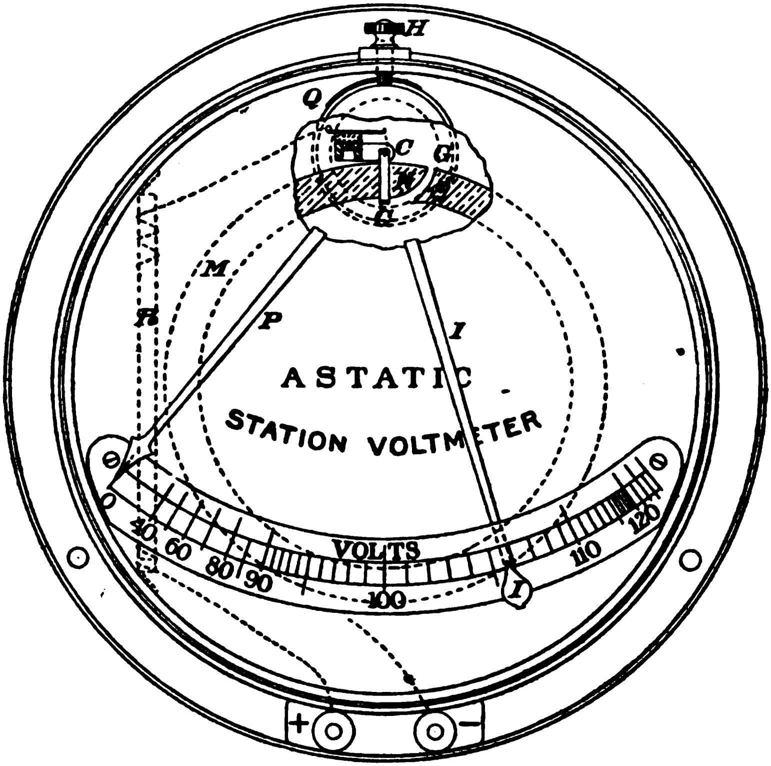

Fig. 2.

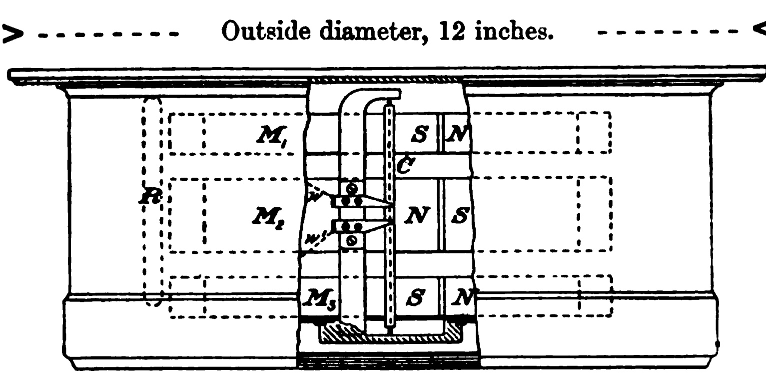

Fig. 3.

red. If the pressure be exactly right, the black index arm is entirely covered by the red pointer; whereas, if the pressure be high or low, black is seen to the left or right of the pointer respectively. An attendant can, therefore, see from a distance of many yards whether the pressure has exactly the desired value, or is above or below it. The same milled head *H* works the arrangement for clamping the moving parts during transport; Professor Ayrton and Mr. Mather.

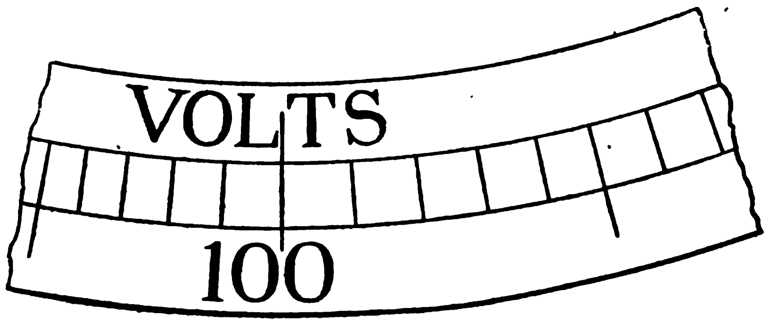

FIG. 4.

but this clamping device is so arranged that the moving parts cannot be clamped as long as the pointer is on any part of the graduated scale; hence there is no risk of the coil and pointer being accidentally clamped while the voltmeter is screwed up to the switch-board. To clamp the moving parts before removing the voltmeter, take out the two side screws that hold the voltmeter to the switch-board, and turn the instrument around the top screw until the pointer is deflected to the left of the graduated scale; then turn the milled head so as to bring the index up to the pointer, when the moving parts will be firmly clamped.

Lastly, the inside of the glass cover is coated with a layer of our transparent conducting varnish, described in the previous paper read to-night, and the instrument is thus screened from outside electrostatic action. Hence there is no fear of a change in the reading being produced by cleaning the glass—a very serious source of error, which is not uncommon with electromagnetic voltmeters in actual use in electric light central stations.

Mr. Mordey. Mr. W. M. Mordey: I should like to congratulate the authors on the feature of the large open scale of this instrument at a particular part of the scale. I think that a most important feature in inspectional instruments. I should like to see instruments for, say, 100-volt circuits with the whole of the scale occupied by the range from 95 to 105. Most of us have repeatedly tried to get instruments that had that feature, but not with much success. Instrument makers, as a rule, have directed their energies to getting proportionality in scales. This is very useful in some cases when you have got it; but it is a very much more important thing when working, for example, with a fixed or only slightly varying E.M.F., as one generally is, to have a very large open scale. By the use of a lens or telescope one could get quite as good a reading on that instrument, apparently, as with, I suppose, a much more expensive reflecting instrument, with all its inconvenience of lamp and scale, and so on. The instrument before us is a permanent magnetic instrument, and only suitable for direct currents; but we should like to have the same features in alternating-current instruments—that is, in voltmeters for the lower pressures, and in ammeters. I hope that the authors will pursue their labours further, and in that direction. I must also congratulate the authors on the conducting screen. I think I was perhaps the first to draw Professor Ayrton's attention to the necessity for something of the sort, or, rather, to the effects that it appears to prevent. I remember he kindly asked me a few years ago, when the first Ayrton-Mather electrostatic instrument was made, to go to South Kensington and examine it. I did so, and I remember that on that occasion he acknowledged that he was unacquainted with the fact, which had only just come to my knowledge, that a disturbance of the needle might arise from static excitation of the glass front.

As regards the astatic quality of the instrument, this is a matter of the very greatest importance, and one which has been almost entirely neglected by makers of instruments intended for ordinary switch-board use. The result of this is that one never can depend upon getting more than an approximation to the value

of the current or pressure. With the large currents and strong fields that are now used, I feel that instrument makers will have to adopt different methods from those now generally obtaining; and I regard the authors' paper as an excellent example, the bearing of which I hope will be quickly perceived and followed. Mr Mordey.

Mr. CROMPTON: The phenomenon described by Professor Ayrton of the electrifying of the glass of these instruments is well known to every switch-board man, and the way to prevent its being a nuisance is equally well known. The remedy is to touch the glass with the finger and so discharge it. No inconvenience has, to my knowledge, ever arisen from these phenomena. We have looked upon them as interesting, and as a show effect to astonish strangers. I do not think Professor Ayrton would have got the phenomena marked so strongly if he had not used the lamps in front of the instrument to warm them up, and if he had not had exceptionally warm and dry weather. I think we are indebted to Professor Ayrton for showing us the remedy. Mr. Crompton.

With regard to his other paper, I am so placed that I have not been able to see the front of the instruments, and can only, therefore, speak from Professor Ayrton's description. I gather from this description that some of the improvements he has mentioned are not new. Professor Ayrton's refinement on Mr. Weston's instruments—*i.e.*, of using three moving coils—is no doubt a very beautiful and effective device, but I should think it has the defect of being excessively costly. This is shown by the price that is now charged for Mr. Weston's instruments; and I should judge from the increased number of coils that the manufacturing cost of the present instrument would be still higher. As it is of importance that instruments that are used in a considerable number should be produced and sold at a reasonable cost, it has been the aim of most of us manufacturers to produce a practically astatic instrument in a less costly manner than that proposed by the author. At the present time the market price of voltmeters is from £3 to £4, and I do not think it would be possible to make the authors' instrument for anything like this sum. For the cheaper instruments I mention, the practical method most commonly employed is to give the instrument as

Mr. Crompton.

strong a field as possible, and use very small soft iron deflecting pieces. By these means we ensure that the instrument is affected by external fields to such a small extent that the error is unnoticeable, or can be allowed for. A common practice is to provide an electric generating station with at least one standard voltmeter of Sir William Thomson's electrostatic type, or of the same character, and provide cheap voltmeters on the switch-board of the type that I have above mentioned. These can be from time to time compared with the standard voltmeter and the difference noted. In this way the practical observations of the E.M.F. of a station can be taken correctly within half a per cent., and this is all that is required. As a constructor of these instruments, I wish to point out that the three coils used by Professor Ayrton must necessarily make the moving parts somewhat heavy, and so make the instrument mechanically more sluggish than it would be if these parts were lighter. With regard to the open scale claimed by the author, I may say at once that this is no novelty. Nearly all makers of these instruments nowadays can, and do, make open scales to order. It is quite the regular thing to have voltmeters specified to be made and calibrated so that the needle hangs exactly vertical at the standard pressure, and that the scale has an open reading of 5 volts on each side of this standard pressure.

Mr. Mordey has said that he requires an equally good instrument for alternating currents; I think he will find no difficulty in getting this in one of the several forms of electrostatic instruments which have recently been perfected.

In bringing forward these criticisms, I must say that, as far as I can see, Professor Ayrton's instrument is certainly a good one, and in several important respects is a decided addition to the good voltmeters that are now available.

Professor Ayrton.

Prof. AYRTON: Mr. Crompton rather implied that I had manufactured a defect in the measuring instrument, and then shown you how to get over it, and that it was rather a feat to show this defect at all. But, as a matter of fact, this electrostatic error in electro-magnetic instruments was originally brought to my notice [illegible] those who had been actually troubled by it in practice. Mr.

Mordey has told you how he was the first to warn me, some years ago, of this cause of vagueness in the readings of these instruments; and shortly afterwards, when visiting a well-known central electric light station of no small importance, I was shown a row of instruments of this particular type which could not be trusted to give accurate readings, partly because the pointers were deflected when the glass fronts were cleaned. I believe a good many specimens of this particular type of instrument may still be seen on the switch-board of central stations, discarded, however, because their indications are untrustworthy. Professor Ayrton.

Mr. Crompton says that it is quite easy to get over the difficulty: you have only got to touch the glass with your finger after rubbing it. Now, curiously enough, the engineer in charge of a central station wrote to me the other day, "I find that earthing "the glass with the fingers *after* rubbing produced more marked "effects than rubbing only;" and this engineer went on to add—which was, however, wrong reasoning; for even central station engineers sometimes reason wrongly—"so that apparently the "front of the glass would require treatment as well as the back." It is not at all an easy matter to thoroughly de-electrify an insulator by simply touching it with your finger. It is well known that by passing a glass rod through a spirit lamp after it has been rubbed you can de-electrify, or if you leave it to itself for a long time it will become discharged; but simply touching it is by no means a certain method of thoroughly discharging it. As to the question of warmth, of course that is the defect of central stations—they cannot keep them cool. If it were possible not to waste any of the heat, and to keep their voltmeters perfectly cool, it is possible that this electrostatic defect would not be troublesome. But with so much waste heat the temperature is by no means low; and as a fan is frequently employed to continuously drive a current of air through the engine room, the instruments are kept thoroughly dry, day after day, and they are therefore quite as dry, if not even drier than those on the table with the glow lamps in front of them; consequently this electrostatic effect cannot help being observed if the glass cover be fairly clean inside and out.

As to the clamping device used in our astatic station voltmeter,

Professor Ayrton.

it is but fair to ourselves to say that we have used this particular clamping arrangement in connection with our electrostatic voltmeters—which are not the subject of this paper—for some three or four years; therefore, although Mr. Crompton may have seen this clamping device before, it is only, I think, on our own instruments that the exact arrangement described in the paper could have been seen, and doubtless he has forgotten where this particular idea originated.

Mr. Crompton considers that the use of a moving coil with a permanent magnet must produce a sluggish instrument. In answer to that, I may say, without hesitation, that he is entirely mistaken; because it is well known that you can increase the force on a coil having only a few ampere-turns to any amount you like, if you only employ a sufficiently powerful stationary magnet. A proof of this is seen from the fact that the watts absorbed in our astatic instrument exhibited on the table are only 1¼ at 100 volts, and we get a pretty quick motion in the needle. The forces are therefore large. It was, in fact, because Mr. Weston employed a moving coil and a powerful permanent magnet that he was enabled to make voltmeters with very high resistance. No *portable* voltmeter was ever made with over 10,000 ohms to measure only 100 volts until Mr. Weston constructed his form.

Mr. SWINBURNE: He has made one of 100,000 ohms with 100 volts.

Professor AYRTON: Mr. Swinburne says that Mr. Weston has made one of 100,000 ohms for 100 volts—a portable instrument. How was he able to attain that result? Simply by utilising the principle which Maxwell was the first to point out, and which Lord Kelvin utilised in his syphon recorder when he wanted to obtain a large electro-magnetic effect with a very small expenditure of energy; the principle being to combine a large powerful stationary magnet with a small moving coil. And if you examine the astatic voltmeter exhibited on the table you will see that the employment of the Maxwell principle has enabled us also to combine small expenditure of energy with considerable rapidity of motion of the pointer. Although we use a gravity control, it is not produced by an auxiliary weight, for the controlling weight is

simply the weight of the triple coil itself; and in that way we do not increase the moment of inertia of the moving system by adding unnecessary mass. We find, as is stated in the paper, that with only 3 per cent. of the whole 7,000 ohms resistance wound on the triple coil we can obtain sufficient force to produce a quick motion of the pointer of a 100-volt instrument. This triple coil, with the three powerful stationary magnets, gives us three times the deflecting couple that would be obtained with one coil, and, as there is only one pair of pivots, we do not have three times the friction. Professor Ayrton.

With regard to Mr. Crompton's criticism as to the price of the instrument, it must not be forgotten that the Weston instruments are made in America, and American workmen are paid twice the wages that workmen are paid in this country, these high wages being possible on account of the large import duty which is levied on goods coming into America from other countries. We must not, therefore, jump to the conclusion that, because the Weston instrument is a very expensive one, all instruments which use moving coils must necessarily be equally expensive.

[*Communicated April* 18*th*]—At the meeting on Thursday last Mr. Crompton suggested—

1st. That the reason why I was able to produce such large deflections of the pointer of the voltmeter by rubbing the glass front with my pocket handkerchief was because the glass had been dried in an exceptional way by the glow lamp which I had placed in front of the instrument to enable its scale to be easily seen in the large lecture theatre at Great George Street.

2nd. That if the glass front were touched with the finger after being rubbed, no error on the reading of the pointer would occur.

3rd. That no deflection of the pointer would be produced if the glass were rubbed with a piece of *oily* waste (this last suggestion was made immediately after the close of the meeting).

As regards criticism No. 1, the glow lamps in front of all the instruments were switched off at 10 p.m. Thursday evening, and all the wires disconnected. On the afternoon of the following day, however, 18 hours after the glow lamps had been turned off,

Professor Ayrton.

and after the voltmeter had been carried back to my laboratory, a touch on the glass with my pocket handkerchief deflected the pointer at once from 0 to 120 volts, where it stayed for some time, neither the glass nor my handkerchief being warmed nor dried in any way. This I repeated several times.

The voltmeter was then left on a table in a *north* room at the Central Technical College, no part of this building having been artifically warmed since April 6th. To-day, April 18th, after four days of rain, I again rubbed the glass cover with my pocket handkerchief, which, like the glass, was neither warmed nor dried. It did not require much rubbing to deflect the pointer from 0 to 100 volts, where it stayed until I de-electrified the glass.

As regards criticism No. 2, it is correct that, if you know what is the position at which the pointer of the voltmeter ought to stand, it is possible, by judiciously dabbing the glass with the finger after rubbing, to bring the pointer to its correct position; but if you do not know what is the true unelectrified position of the pointer, it is quite possible to leave it in a wrong position in spite of the glass being touched with the hand. Indeed, the engineer in charge of one of the principal London central stations wrote to me the other day: "I find that earthing the glass with " the fingers *after* rubbing, produced more marked effects than " rubbing only."

As regards criticism No. 3, Mr. Mather and I dipped a piece of ordinary engine-room waste into oil and rubbed the glass cover of the voltmeter: the pointer at once went from 0 to the other end of the scale, where it stayed. Continued rubbing with the waste appeared to de-electrify the glass, but, on dipping the waste again into the oil, and smearing it on the glass, the pointer was again deflected *exactly* as if the glass were quite clean. Neither the glass, oil, nor waste were warmed or dried.

This idea that a layer of oil prevents glass from being electrified when rubbed is a common mistake, and is one that I was myself under until a few years ago. And I did not realise that it was a mistake until I saw Mrs. Ayrton experimenting on the action produced by light on the shape of electrified drops of oil. During these experiments she frequently dipped a stick of

sealing-wax into oil and rubbed it with an oily piece of flannel, and she noticed incidentally that the sealing-wax was in this way as easily, if not more easily, electrified, than it was when it and the flannel were quite clean. Professor Ayrton.

I think, however, that it may be quite possible to accidentally bring glass into a condition such that it cannot temporarily be electrified, for on first rubbing a glass rod with a piece of silk it is not unusual to find the glass *negatively* electrified, the charge becoming reversed on continued rubbing. Hence, there may be an intermediate condition of the glass and silk when no electrification is produced. And our experiments made with the oily waste appear to show that with a certain thickness of the layer of oil on the glass it is in this intermediate condition. A voltmeter, however, ought to indicate, without doubt, the true pressure between the mains, and the dynamo attendant ought not to have first to divine it in some way, and then do enough rubbing of the glass cover with his oily waste to make the instrument indicate it.

In bringing the matter before the Institution we assumed, from the remarks that central station engineers have made to Mr. Mather and myself during the past four years, that this electrostatic source of error was recognised by them, and had been, at any rate, one of the reasons why certain types of voltmeters on the switch-boards of central stations had come to be regarded as untrustworthy, and were, therefore, no longer used. Our object, therefore, was not to prove that this cause of error existed, but to illustrate how the inner side of the glass cover could be coated in a comparatively simple way with a transparent conducting varnish, so that whether the glass were hot or cold, wet or dry, oily or clean, no attraction of the pointer could be produced electrostatically.

The CHAIRMAN: It is my pleasant duty to propose a vote of thanks to Professor Ayrton, Mr. Whitehead, and Mr. Mather, for the four papers that have been read and discussed on the last occasion and this evening. I think we should pass this vote of thanks with greater pleasure because Professor Ayrton came forward on such short notice with these papers, and filled up a most awkward gap between other papers. Mr. Crompton.

The motion was carried by acclamation.

The Chairman announced that the following candidates had been duly elected :—

Members :

Henry Robert John Burstall.	Alexander William Stewart.

Associates :

Howard Tindall Adlard.	Gustaf Charles Lundberg.
Malcolm H. Butcher.	David Mair.
Charles Langstone.	George J. T. Parfitt.
J. H. Lee.	Frederick William Sedgwick.
Andreas Peter Lundberg.	Thomas Wright.

Students :

T. D. Clothier.	Alec William Quennell.
Dennis H. Felce.	Bernard J. Shillito.
Herbert Grimwood.	Frederick S. Spiers.
Frank Tracy Hamilton.	Frank Charles Thomas.
Simon L. F. McLauchlan.	James Toulmin.

James Edward Salusbury Trelawny.

The meeting then adjourned.

The Two Hundred and Sixty-fourth Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, April 26th, 1894—Mr. R. E. CROMPTON, M. Inst. C.E., Vice-President, in the Chair.

The minutes of the Ordinary General Meeting of April 12th were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

James Hardie McLean.

From the class of Students to that of Associates—

Leonard Barlow.
Cuthbert W. Barnes.
J. R. Craddock.
H. J. Edwards.
J. E. Pierce.
Charles Edmund S. Phillips.
W. M. Rogerson.
Arthur Fox Ward.
Norman Ward.

Mr. W. H. Handcock and Mr. P. Dawson were appointed scrutineers of the ballot for new members.

The CHAIRMAN: I will now vacate the chair in order to read my paper.

Sir David Salomons, V.P., occupied the chair during the remainder of the evening.

COST OF ELECTRICAL ENERGY.

By R. E. Crompton, M. Inst. C.E., Vice-President.

Mr. Crompton.

I address this paper to all who are interested in electrical supply, but especially to the engineers who design and who work electrical supply plant. It is almost exactly six years since I read a paper before this Institution* on this subject, and three years since I read a similar paper before the Institution of Civil Engineers.†

I should be glad if those who are really interested in the subject would find time to glance over these two papers after reading the present one, as there is much contained in them which might have been repeated here with advantage if I had not feared to unduly lengthen the paper.

For convenience and brevity I use the word "works" for the whole plant of an electric supply company; such works may have several generating stations. I use throughout the word "energy" for the electrical energy, and I speak of the two well-known systems of distribution as "direct" or "converted" systems. By direct systems I mean all two, three, or other multiple wire systems, with or without storage, in which the energy is supplied direct from the dynamos to the mains, and from the mains to the users, without change of pressure. I include amongst converted systems all those in which the energy is either generated at a high pressure, or converted up to a high pressure for transmission through the mains, and afterwards converted to the lower pressure at which it is supplied to the users.

In this paper I do not deal with works using water power, but solely with those in which the electrical energy is obtained from fuel.

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* *Jour. Inst. E.E.*, vol. xvii., p. 349.

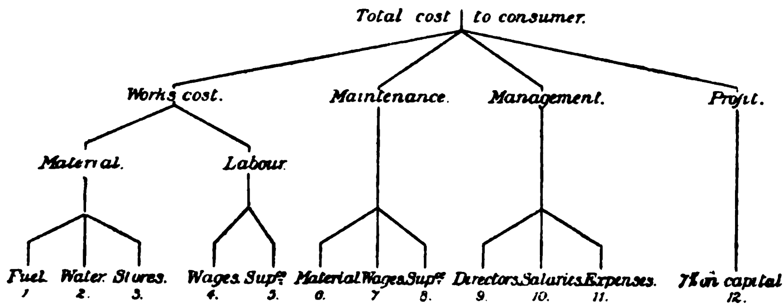
† *Proc. Inst. C.E.*, vol. cvi., p 2.

The total cost to the user may be grouped under four heads— Mr. Crompton.

Works Cost; Maintenance; Management; Profit.

These may be conveniently subdivided into 12 sub-heads or divisions, as follows:—

Table I.



Of these 12 heads I propose to deal at length with 1 to 8 only. The remaining heads of Management and Profit are outside the province of us engineers, except in one important particular, which is that the interest or profit to be paid on the capital employed is affected by the choice of system used, and by the skill of the designer of the works, so that it is necessary for us to deal with it.

Let us assume that our ideal works are designed for the most economical production of 5,000,000 units of energy per annum, distributed to users in a large town and under average conditions. We are now in a position to estimate with considerable accuracy that the capital required for the preliminary expenses, for obtaining the requisite Parliamentary powers, and for the complete equipment of such works will not exceed £500,000, or at the rate of 2s. per unit sold per annum. I have arrived at this figure after considerable study of the capital account of existing companies, and of works carried out by local authorities, and I find that it is nearly certain that several existing works will reach this figure as soon as their plant is completed to the scale intended, and worked to the full output; so that, if we consider that entirely new works could now be certainly carried out at a lower cost than

Mr. Crompton. that of any existing works, it will be seen that my estimate is on the safe side.

Now I think that such works ought to be able to include in the total cost to the consumer such a sum as profit as will yield 7 per cent. per annum on the whole of the loan as well as subscribed capital. In the case of a local authority, a portion of this 7 per cent. would be applied to paying the interest and sinking fund on the original loan, and the remainder would be applied as a profit in the reduction of local burdens or in introducing local improvements; but in the case of a joint-stock company this capital of £500,000 might advantageously consist of £200,000 in ordinary shares, £100,000 in 6 per cent. preference stock, and £200,000 in 4 per cent. debenture stock, so that the average of 7 per cent. on the whole £500,000 might be divided up as follows:—

4 per cent. on debenture stock	...	£8,000
6 per cent. on preference stock	...	6,000
10½ per cent. on ordinary stock	...	21,000
Total	...	£35,000

This sum of £35,000 is equal to a profit of 1·68d. per unit sold. The cost of managing such a company can also be dismissed in a few words. Under this heading it is convenient to group directors' fees, salaries of managing staff and office, meter readers, collectors, all stationery, law, and audit charges, rates, taxes, and insurance. If we take the practice of the best-managed works as a guide, we find that about £8,200 per annum is sufficient to cover all these charges for the largest output that has been yet obtained. It is evident that a sum of £9,000 a year would be an ample one for the management charge on the output of 5,000,000 units. This management charge therefore works out at 0·42d. a unit.

You will see, then, that at the scale of working that we are now considering, which is at a scale of output certain to be reached within a year or two by a large number of works, the

Mr. Crompton

management and profit items, taken together, should amount to 2·1d. per unit. As I have said above, we engineers have nothing to say in controlling these figures. They are certain to be reached in course of a few years, as it is a mere question of output. The question which I now propose for your consideration is this: What chance have we of reducing the present works cost and maintenance cost included in the sub-heads 1 to 8 to such an extent that the energy may be sold to the public at, possibly, the low figure of 3d. per unit? I believe that Mr. Swinburne has stated that electrical energy, whenever the demand is continuous, such as for certain electrolytic or electro-metallurgical processes, can be generated and distributed to short distances at a works and maintenance cost of ¼d. a unit. I believe Mr. Swinburne has good grounds for this estimate, if cheap fuel is available. But for our present purpose, which chiefly concerns the supply of electrical energy used largely for electric lighting, and to a minor degree for power, we cannot fix such a low figure for our ideal works and maintenance cost for the future. Mr. Swinburne's case and those which we are now considering differ so widely. We can hardly hope for many years to come to improve the load-factors of works for general supply much above 20. The average of the London stations is still a long way off this figure, and I fear that the extensions of the use of energy for power and purposes other than lighting are likely to go on for some years to come at a slow rate. At a load-factor of 20 you must remember that all maintenance charges work out nearly five times as great as they would be if the output was continuous. It is useless to put before you ideal figures which we cannot hope to approach. I propose, instead, to adopt figures which we may hope to reach at no distant period, and have therefore prepared those given on Table II., and I give reasons for fixing on them as I deal with each subhead in turn.

Mr. Crompton.

Table II.—Ideal Standard Works Cost.

		d.	d.
Works Cost—	Cost per Unit Sold.		
1.	Fuel—2·5 lbs. Welsh coal at 20s.	0·27	
2.	Water	0·01	
3.	Petty stores	0·02	
4.	Wages	0·10	
5.	Superintendence	0·10	
	Total works cost	——	0·5
Maintenance—			
6.	Material on repairs	0·20	
7.	Wages on repairs	0·15	
8.	Superintendence	0·05	
		——	0·4
9. 10. 11.	Management		0·42
12.	Profit		1·68
			3·00

Working expenses, 44 % of receipts.

FUEL AND WATER.—DIVS. 1 AND 2.—FUEL.

I agree with Professor Kennedy in the remarks that he made on my paper read before the Institution of Civil Engineers* that the importance of the cost of the fuel used on electrical energy supply works is not to be measured merely by the money spent on the fuel itself, but that it is to a certain extent a measure of the quantity of plant that must be employed, and so affects the cost of upkeep of the plant, and to some extent every cost item, except, perhaps, management and profit items.

At a very early stage in the history of electrical supply works it was found that in practice the amount and cost of the fuel used differed very widely from the amount estimated from the known efficiency of the plant.

In 1883 modern engine builders were making engines and boilers using less than 2½ lbs. of good coal per I.H.P., and the mechanical efficiency of these engines was certainly not less than 85 per cent. At that time dynamos could be made of 85 per cent. efficiency. We all thought that our distribution losses

* *Proc. Inst. C.E.*, vol. cvi., p. 2.

should not exceed 15 per cent.; so that, putting these figures together, we were justified in hoping that our fuel bill would not exceed 5½ lbs. of coal per unit sold. We soon, however, found that in practice we could not approach such a degree of economy; so that the opinions of practical engineers in charge of supply works rapidly veered round to the opposite extreme, and among these gentlemen, even in 1888, when I estimated that the figure which was then prevalent of about 24 lbs. of good Welsh coal used per unit sold might in the future be reduced to 5¾ lbs., I met with much incredulity. At so late a date as that of my paper before the Institution of Civil Engineers in 1891,* Mr. Raworth, in the course of discussion, stated that to his knowledge from 19 to 22 lbs. of coal was commonly being used, and that he considered the figures I then gave—namely, 7·9 lbs. for the Kensington and 6·5 lbs. for St. James's stations, for the best months of the year—were so satisfactory that they opened up a prospect of a new era for shareholders in those companies. I am glad to say that since that date improvement has been very regular; during the past year we have several times seen recorded during the winter months—in which, of course, the economy of fuel is at its best—a fuel consumption under 5 lbs. of Welsh coal per unit sold; so that my forecast, made six years ago, has already been more than justified.

Mr. Crompton

I have arrived at my new possible or ideal figure of 2½ lbs. of Welsh coal per unit sold in the following manner:—I find that we can in London count on obtaining this coal having an average calorific value of 14,500 B.T.U. per lb. With proper arrangements for heating the feed water to nearly boiling point boilers can be obtained which will evaporate 12 lbs. of water at our working pressure of 150 lbs. I think that the losses due to irregular working and banking fires can be so minimised that 2½ lbs. may evaporate 25 lbs. of water into dry steam—not on tests only, but as shown on the monthly bills. Condensing steam engines can and will be made for us using not more than 12 lbs. of steam at from three-quarters to full load, or 13 lbs. of steam at from

* *Proc. Inst. C.E.*, vol. cvi., p. 2.

Mr. Crompton.

half to three-quarters load per I.H.P. per hour. To these engines dynamos can be coupled direct of such efficiency that the combination will not use more than 18½ lbs. to 20½ lbs. of steam per unit per hour, measured at the dynamo terminals at the corresponding loads, so that an average of 20 lbs. per unit generated may be counted on during the time that these engines are actually at work. This allows for 10 per cent. of the steam evaporated being condensed in the pipes, or used in feed pumps or other obscure sources of loss, and a further 10 per cent. for our distribution loss, in order to account for the 25 lbs. of water I require to be evaporated by the boilers.

It appears to me that the most convenient method of discussing the problem of reaching these ideal figures is to consider in turn the fuel that we use and the boilers and other steam-producing apparatus, the engines for using the steam, the dynamos for generating the energy, and, finally, the means for distributing the energy to the users—in each case with a view of locating the losses that now take place, and considering the best means of minimising these losses as far as may be possible.

In London the favourite fuel hitherto used in electric supply works has been Welsh coal of the best quality, as it has been found that the cost of the carriage of fuel forms such a large part of its total cost when delivered on to the works, that in most cases it pays best to use nothing but fuel of the highest calorific value. This value in the case of the best Welsh coals may be taken at 14,500 British thermal units; for, although values as high as 16,700 have been noted in the case of Nixon's and a few other Welsh coals, yet is probable that these exceptional values are not attained on the average, even from coals from the very same seam.

As our ideal figure of 2½ lbs. therefore contains 36,250 B.T.U., it will be convenient, for purposes of comparison, or for considering the use of other fuels, to point out that 2½ lbs. of Welsh coal is equal to 36¼ B.T.U. per watt-hour of the energy sold.

Table V. gives the calorific values of various fuels, determined by Bryan, Donkin, & Co., Limited, arranged in the order of their efficiency when used in a Lancashire boiler fitted with Perret's furnace.

Mr. Crompton.

Table V.—Calorific Values of various Fuels, determined by Messrs. Bryan, Donkin & Co., Limited.

Fuel.	Description.	Where from.	Value in B. Ther. U.	Evaporation in Boiler per Lb. of Fuel, Lbs. of Water from 80° F. at 50 Lbs. Press.	Clinkers and Ash, &c.	Efficiency of Boiler.
						%
Coal	Large	Welsh, best	15,500	10·0	2·4	66·5
,, ...	Small	Cheshire, Orrel Col. Co.	14,500	8·7	2·4	64·0
,, ...	Large	Welsh, Ocean	13,950	7·9	8·5	58·7
Anthracite	Pea	,, Llanelly	13,840	7·7	5·2	57·0
,,	Nuts	,, ,, ...	13,560	7·7	6·6	58·5
Coal	Large	,, Ffaldau	13,560	7·7	9·5	58·5
,, ...	,, ...	Yorkshire, Ravensworth	14,820	7·5	10·5	51·0
Coke	,, ...	London	...	6·85	...	...
Coal	Dust	Welsh	...	6·78	7·1	...
,, ...	Small	Nottingham	11,630	6·5	12·9	58.0
Anthracite	Dust	Welsh	13,700	6·35	6·2	47·0
Coke (ord.)	Breeze	London	10,610	5·4	19·6	52·5
Coke	,, ...	Welsh (Ebbw)	12,000	5·4	5·5	46·0
,, ...	Dust Breeze ...	Nottingham	11,200	3·7	20·0	33·8
,, (pan)	Breeze	London	8,840	3·32	28·6	...
Refuse ...	House (unsorted)	,, ...	...	2·13	...	...

I have been enabled, through the kindness of Messrs. Bryan, Donkin, & Co., to avail myself of these figures, which show at a glance the (comparative) value of Welsh coal as compared with other steam coals, of large Welsh as compared with small Welsh, of small anthracite, large and small coke, and coke dust; and, for the information of those who hope for great things from the use of town refuse for steam-raising purposes, I give at the foot of this table Messrs. Bryan & Donkin's determination of its value. The Perret furnaces used for these determinations is well suited for making such a comparison, as it burns efficiently all classes of fuel, even the smaller and finely divided coals, coal dust, coke breeze, and coke dust, and in these cases minimises the loss of small combustible, which is liable to fall through the grate bars. The results shown on this table emphasise the fact that in practice we can utilise a large percentage of the T.U. in such

Mr. Crompton

fuels as anthracite, Welsh coal, and coke, the heating power of which lies chiefly in the solid carbon which they contain; and that the small and dust fuels of the same class are only less valuable because a part of them is liable to fall through the bars, and because, being so finely divided, they usually contain more earthy matter to form clinker and ash in the furnace than the larger coals or cokes, which can be more easily hand-picked, sorted, or washed free from such impurities.

The very large class of steam coals used in the Midlands and North is only represented in the table by the one test of the Yorkshire Ravensworth coal, but the majority of these coals, whether large engine coal, nuts, or engine slack, only contain from 50 to 70 per cent. of carbon in the solid form; so that, although, on account of the T.U. contained in the combined carbon and in the hydrogen, these fuels, when tested in the calorimeter, may give a calorific efficiency approaching that of the anthracite and Welsh coals, yet we find very rarely that any form of furnace now in use is able to utilise any considerable percentage of these hydrogen units, even when the best of the modern automatic stoking apparatus is used. So that when judging the comparative value of these fuels we should always remember that it is far more difficult to obtain a high boiler efficiency from these latter fuels than from those which contain the larger percentage of carbon in the form of coke. In order that you may conveniently calculate the T.U. contained in a pennyworth of coal of various qualities and prices, I have prepared Table V. (*a*), which shows this at a glance for all fuels from 10,000 up to 16,000 B.T.U. per lb., and for all prices from 5s. up to 22s. per ton.

Fuel and Water.—Divs. 1 and 2.—Boilers, Economisers, &c.

The boilers which have hitherto been chiefly used in electric supply works have been of the locomotive, marine or semi-marine, tubulous, or Babcock & Wilcox type, and the Lancashire type.

Locomotive Type.—Several large locomotive boilers were put in by Mr. W. H. Maw for driving the *Daily Telegraph* printing works, and the success of these was so great that I asked him to

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ous Qualities and Prices.

H Un lb.	19/-	20/-	21/-	22/-
1	...	...	...	...
1	...	...	...	...
1	...	...	...	...
1	...	...	...	...
0	...	...	...	...
0	108000	...	...	...
0	110000	104500	...	...
0	112000	106400	101300	...
0	114000	108300	103100	98400
0	116000	110200	104900	100100
0	118000	112000	106700	101800
0	120000	113900	108400	103500
0	121700	115800	110200	105200
0	123600	117600	112000	106900
0	125700	119500	113800	108500
0	127500	121400	115600	110300
0	129500	123200	117300	112000
0	131750	125100	119100	113700
0	133500	127000	120900	115700
0	135750	128800	122700	117100
0	137500	130700	124400	118800
0	139500	132500	126200	120500
0	141500	134400	128000	122200
0	143500	136300	129700	123900
0	145500	138100	131500	125600
0	147200	140000	133300	127300
0	149100	141900	135100	129000
0	151000	143700	136900	130700
0	153000	145600	138600	132400
0	155000	147500	140400	134100
0	157000	149800	142200	135800

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design for me boilers of the same type for the first London central station, which my firm put down for the London, Chatham, and Dover Railway at Victoria Station in 1883. These boilers had copper fire-boxes, and, on test trials, gave an evaporative efficiency of 8½ to 9 lbs. of water per lb. of Welsh coal. This type is in most respects satisfactory; but, on account of the level of the grate bars being so much below the level of the fire doors, it is difficult to properly clinker the fires—so much so that when a batch of coal is used that contains much clinker it is very difficult to clean the fires in a reasonable time, so that the evaporative efficiency is thereby much reduced. From this cause the average efficiency of locomotive boilers does not much exceed 7 lbs. of water per lb. of coal when taken from the monthly bills, and under the conditions usually met with in supply works. It is also not an easy matter to bank the fires of a locomotive boiler in an economical manner. Mr. Crompton.

The St. James and Pall Mall Co. have used large boilers of this type made by Davey, Paxman, & Co.; and the Metropolitan Co. have used others made by Hornsbys—all, I believe, with good results. I, however, have been unable to obtain the correct evaporative duty. This type of boiler is rather more costly to maintain than the other types; the fire door ring is liable to give trouble from leakage, and a great deal of space must be wasted in order to give access to the smoke-box end of the boilers for tube-sweeping purposes.

The Marine and Semi-Marine Type.—The marine type has been used in a few instances, notably in the Whitehall Court station of the Metropolitan Company, and is highly economical; but it is a rather costly boiler to construct. Equally good results may be obtained from the semi-marine type, which is a modification of it, made by Messrs. Davey Paxman and others, which they call the "Economic" boiler; in this boiler the flues are carried right through from front to back, and the products of combustion are deflected back through the tubes by a firebrick back. In Scotland this boiler is called a "dry back" boiler. It has many merits: it is very simple, and easily repaired; the intensely heated "dry-back" acts as a very good smoke preventer, so that Midland steam coals can be used

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without producing smoke, which is not the case with either the locomotive or Babcock's type. Professor Kennedy has used a large number of these boilers for the Westminster Supply Co., and, he tells me, with uniformly good results from every point of view. The test of this boiler given in Table IV. shows it to be of the highest efficiency. I have not personally had much experience in its use until quite recently at the new central station in Shoreditch for the Great Eastern Railway. The sole fault in this boiler (and it is not a great one) is the rather awkward position of the smoke-box over the fire door.

Babcock & Wilcox Boilers.—These boilers, as you well know, consist of a large group of inclined tubes, having the water inside the tubes, the highest end of the tubes being at the firing end of the boiler. The tubes are connected at both ends by special headers to steam drums placed overhead. The firing is carried on on large grates, and the products of combustion are deflected by fire-tile bridges so that they are obliged to follow a serpentine course through the tubes, the hot gases passing several times transversely to the tubes. My experience in the use of Babcock boilers has been altogether satisfactory, and I believe that the best evaporative efficiency yet obtained in supply works has been with these boilers. I make this statement all the more readily as in my 1891 paper* I said that this class of boiler, presenting as it does such considerable radiating surface of brickwork, would not give such economical results during the long hours of standing with banked fires as other boilers which are internally fired; but since that date the skill of the designers, and the great skill and attention of the users, has resulted in so minimising these losses that I believe these boilers stand quite at the head of the list, not only as regards economical working on full-load tests, but also in the small use of fuel when standing banked. These are my own observations, but I understand that the experience of others has been equally satisfactory, at least wherever Welsh, anthracite, coke, or other smokeless fuels are used. I am told that when used with smoke-producing fuel there is a tendency for the lower row of tubes to cool down the products

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of combustion, that these tubes become coated with soot, and the evaporative result is unsatisfactory. I believe, however, that the makers have now introduced special means to get over this difficulty. The chief refinements that those who use these boilers have been able to introduce, and which have led to reduction in the waste of fuel during long hours of light firing and banking, are principally in the alteration of ash-pit, flue doors, and dampers, so as to regulate the air admission with great nicety, or to completely shut it off. We also find that the maintenance of the fire-tile bridges between the tubes which cause the gases to follow the undulating path above described is a matter of extreme importance; and last, but not least, this boiler should be kept perfectly clean. Up to a few years ago we were content with periodical cleanings and scalings; but now, by the use of suitable boiler fluids and frequent blowing off at the surface as well as at the lower cocks, we find that we can keep the interior of these boilers as free from scale, and in all respects as clean, as when they left the makers' hands. Test results with these boilers have shown that 9¾ lbs. of water can be evaporated with Welsh coal at 170 lbs. boiler pressure: if the calorific value of this coal is taken at 15,000, this is equal to 76½ per cent. efficiency; and, as my table of costs will show you, in practice we have reached to within a narrow percentage of this figure, even when all banking coal and other sources of waste are taken into consideration.

Lancashire Boilers.—We are told from time to time that the evaporative efficiency of this boiler ought to be the highest, and its maintenance cost the lowest, of any boiler. I believe the latter claim to be better founded than the former. The boiler is easy to clean, and the repairs should be few at low pressures and far between; but it must be remembered that we have no extended experience of the cost of maintenance of these boilers when used at the higher pressures of 140 to 170 lbs. per square inch, now so common in electric works—as, for instance, the maintenance of the usual fusible plug is not an easy matter, and it is therefore necessary to depend on some form of low-water alarm, which is always a troublesome piece of apparatus; again, although the accidental lowering of the water level of a locomotive or a Babcock boiler or an "Economic" boiler may have serious

Mr. Crompton. consequences, yet these are nothing to what occurs when the flues of a Lancashire boiler come down from this cause.

As regards the evaporative efficiency of the Lancashire boiler, I think it has been somewhat overrated. Owing to the fact that the great majority of Lancashire boilers are in use in the Midland and Northern counties, where the fuel used is cheaper than that we use in London, and where little or nothing is said if smoke is produced, and where low cost of maintenance is of higher importance than high evaporative efficiency, mill engineers have been led to regard this as the one and only boiler; but that this type is not efficient when taken by itself, is amply proved by the fact that no first-class mill is ever fitted up without the addition of economisers—in fact, we may say that the Lancashire boiler without its economiser is only half a boiler. In most cases the gases would leave the Lancashire boiler at 700 degrees, leaving 300 degrees to be taken out of the gases by the economiser; whereas in tests of the locomotive, marine, semi-marine, or Babcock boilers the gases leave the boiler itself at a temperature very slightly in excess of that of the steam; so that in this latter case an economiser would be a refinement, and not a necessity. I do not think this fact has been sufficiently brought home to us engineers when the merits of the Lancashire type of boiler have been so persistently put before us by outside engineers, so that many of us—myself included—have made the mistake of putting down Lancashire boilers for supply stations in country towns without economisers, thinking that if we made these boilers large for their work we should get the required economy, whereas with this type the only way to get high economy is to use a rather small boiler and a large economiser. At any rate, the electric works using Lancashire boilers have hitherto not shown at all well in comparison with other types. In towns where the fuel is obtained so near to the works that the cost of carriage is small compared with the actual cost of the fuel itself, it pays to put down boilers fitted with special stoking plant to deal with these inferior fuels. In most of these cases Lancashire boilers have been used, but, as I shall show hereafter, the results hitherto obtained from the use of such cheap fuel have not

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been very satisfactory; in fact, the very cheapness of the fuel itself has been a snare to the works engineers, causing them to neglect refinements in fuel economy to such an extent that in many cases the greater part of the saving which they ought to have shown from the low price of their fuel has been lost. In some cases the price of their fuel has been actually higher than in the best London works, where economical working has been studied.

It is now time to put before you in a tabular form the data which I have been able to prepare to show the working efficiency of the boiler plant used in 10 of the works which I propose to compare. In all cases the quantity and calorific value of the fuel used is given with sufficient accuracy; but I have not in all cases been able to ascertain the water used per unit with the same accuracy, although this would have been a very desirable check on my other figures.

Table III. shows the actual boiler efficiency observed in these 10 works; I have designated them by letters, which enable you to identify them, in the following tables.

Table III.—Boiler Efficiency.

Works.	System.	Type of Boiler.	Fuel.		Lbs. of Fuel per Unit Sold.		Lbs. of Water Evaporated per Lb. of Fuel.	Efficiency of Boiler.
			Class.	Value in B.T.U.	1892.	1893.		
								%
E	"Converted" Alternating	Lancashire ...	Small...	11,300	21·0	23·0	4·12	38·0
N	"Direct"... ...	,, ...	,, ..	12,000	17·7	17·1	5·0 ?	43 5
O	,, ...	,, ...	,, ...	12,000	16·6	17·0	6·0 ?	52 0
J	$\frac{1}{2}$ "Converted" Alternating $\frac{1}{2}$ "Direct"	,, ...	,, ...	12,000	16·0	14·8	5·2	45·2
I	$\frac{1}{2}$ "Converted" Alternating $\frac{1}{2}$ "Direct"...	Babcock & Wilcox ...	Welsh	14,500	14·7	12·0	7·8	56·5
Q	"Direct"	Locomotive	$\frac{3}{4}$ Welsh $\frac{1}{4}$ Coke	...	...	10·2	7·5	54·5
U	,, ...	Babcock & Wilcox ...	Welsh	14,500	8·9	8·0	7·85	57·0
V	,, ...	Economic ...	,,	14,500	9·9	7·5	8·0	58 0
W	,, ...	Babcock & Wilcox ...	,,	14,500	6·9	5·83	8·5	61·5

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In all the tables they are arranged in the actual order of fuel economy, E showing the largest consumption of fuel per unit sold, and W the smallest.

Table IV. gives the evaporative duty and efficiency of several types of boiler determined at special tests.

Table IV.—Recording Maximum Efficiency of sundry Types of Boilers at Test Trials.

By whom carried on.	Boiler.	Fuel Used. Description.	Fuel Used. Cal. Value.	Lbs. Water Evaporated. From and at 212°.	Lbs. Water Evaporated. From 170° to 180°.	Efficiency.
						%
J. F. Crosland ...	Lancashire	Lofthouse unscreened nuts	12,875	7 74	...	56·5
,, ...	With McPhail & Simpson's superheater	,, ,,	12,723	10·05	9·3	76·3
J. Holliday, at Messrs. Bryan Donkin's works	Perret's grate with Lancashire	Welsh small	16,734	9·96	9·2	65·9
,, ,,	,, ,,	Coke dust	8,400	6·02	5.5	69·3
Prof. Robinson, at St. Pancras	Babcock & Wilcox	Welsh ...	15,000	11·9	11·0	76·5
Prof. Kennedy, at Glasgow	Marine type... ...	Coke	12,120	7·91	7·3	63·0
Prof. Kennedy, at Eccleston Place	Semi-marine type	Welsh ...	14,866	12·2	11·25	78·0
Prof. Kennedy, 26th Nov., 1888	Thornycroft water-tube boiler	,, ..	14,900	13·4	12·4	86·8

I would draw attention to the remarkably high results obtained by Professor Kennedy, shown on Table IV., in his Glasgow trials; and beg that this result, which was obtained with marine-type boilers using small gas works coke, may be compared with that shown by Bryan Donkin, in Table V., with a Lancashire boiler using similar coke.

Referring to Table III., Works J are using Lancashire boilers

fitted with automatic stokers of the Vicars type. In this case, which is under my own control, every means has been studied to increase the evaporative efficiency of the boilers; but this is a typical case of the difficulties attending the use of small coal, even if it be of fairly high calorific value. In this case a considerable part of the loss is due to the small coal falling through the bars. The coal supplied is of variable caking quality: sometimes it cakes together sufficiently to reduce this loss; in other cases it hardly cakes at all, and from 15 to 20 per cent. of the combustible is lost. The point I have above referred to of the extreme difficulty of utilising the heat units in the hydrogen is here met with. If the air admission is not managed with the utmost nicety, the losses due to over-dilution of the products of combustion by air become so great that the evaporation is largely diminished, and this without any apparent neglect on the part of the stoker. Mr. Crompton.

Before leaving the subject of boilers, I ought to say a few words on the use of forced draught. A good many of us have formed the opinion that one of the best methods of meeting the short period of heavy load is by the use of forced draught applied to a closed ash-pit, as has been done by Meldrun and others. It is evident that existing boiler plant might in case of emergency, or for short periods, be forced to evaporate 50 per cent. more steam than at present; and this would be particularly convenient to meet the times of maximum load, so that in this way the waste of fuel due to lighting up extra boilers for these short periods might be reduced or altogether avoided. We should also be able to burn small or finely divided, and hence cheaper, fuel during the times of light load in an efficient manner. Another method of reducing the cost due to the necessity of lighting up additional boilers for the period of maximum load would be by using liquid fuel, to be used only on emergency or during these periods of maximum load.

As is well known, Mr. Holden, on the Great Eastern Railway, has been very successful in the use of astatki, or crude petroleum, with his works boilers, and on some of the locomotives of the Great Eastern Railway. The principal objection to his system

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appears to be the noise of the blower, and the same applies to nearly all the systems of forced draught where an injector blower is used; but there seems little doubt that this noise may be minimised by properly arranging the air inlet—that is to say, by drawing the air from a point outside the building, placed so that the noise at the entrance cannot be a nuisance to the neighbours. As it is evident that it is very easy and convenient to safely store such liquid fuel in deep underground tanks, and as is evident, in face of the troubles we have lately gone through from the coal strike, that it is necessary to have such a considerable storage, this question of the employment of liquid fuel deserves careful attention by all interested in supply works.

There is another point to which I wish to call attention. A long and interesting series of articles has recently appeared on water-tube boilers in the *Engineer*, in the course of which the writer more than once states that it is impossible to force any of the existing types of water-tube boilers, as any such forcing invariably results in the production of wet steam, and consequent loss of economy. It is difficult to know how the writer could have formed such an erroneous impression. My own experience is that the works where the best results have been obtained are those where the Babcock & Wilcox boilers have been forced the hardest. At Works W, the boilers, which are nominally supposed to evaporate 11,000 lbs. of water per hour, have frequently been forced to 16,000, or about 50 per cent. in excess of the duty guaranteed by the makers, and at such times of heavy forcing there has never been any trace of priming or wet steam.

On the whole, I think that there is a fair prospect of improving and supplementing our boiler plant and our methods of working it so that we may obtain in the future an average boiler efficiency of 70 per cent.—equivalent to an evaporation of 10 lbs. of water at a pressure of 150 lbs. when using Welsh coal, and an equivalent smaller evaporation from inferior and lower-priced coal.

Fuel and Water.—Divs. 1 and 2.—The Effect of the Efficiency of Steam Engines on Dynamos or Alternators.

Now that so many supply works have been running for several

years, and that the works accounts have been annually published in the full detail demanded by the Board of Trade requirements, so that the actual cost of fuel, water, stores, labour and salaries, and actual output of energy delivered, are recorded, and are known to everyone who interests himself in these matters, it might be thought an easy matter to draw some useful conclusions from these published figures, so as to throw light on the comparative efficiency of the various systems and types of plant used in these supply works; but I regret to be obliged to confess that the drawing up of such comparative tables is not an easy matter. I have examined the published accounts of 23 important and representative electric supply works, in order to compare for this part of the paper the cost of the fuel. From these I have prepared Table VI., which relates solely to fuel and water used. I must mention that in preparing this and the other tables I at first relied on the published accounts for the information as to fuel, stores, labour, and salaries; but, as I found that several serious mistakes existed in the published analysis of such accounts, I in every case have taken the precaution of sending the figures to the engineer of each works, in order that he might satisfy himself of their correctness, and in most cases the engineers of these works have very kindly supplemented this figure by the other data required to bring this cost of fuel to a common basis for purposes of comparison. Mr. Crompton.

The best method of comparing the comparative efficiency of the generating plant would be by comparing the weight of water evaporated per unit generated; but, as I have already pointed out when discussing the boiler question, this water measurement has been very rarely carried out, so that I am obliged to fall back upon the only certain measurement—that is, the weight of fuel used. I have written to all the engineers of the works named in these tables, and have in some cases received full information, in others partial information, and in a few cases have been refused all supplementary information. In the cases where the information has been partially, or where it has been entirely withheld, I have been obliged myself to fill in the blanks by calculating them from the published costs and known calorific values of the fuel

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used. I have done this after having made careful inquiry in each case; and whenever there has been a doubt as to quantity, price, or calorific value, I have endeavoured in each case rather to favour that particular works. At any rate, any errors that may exist in these calculated figures cannot be large enough to affect the result which I now bring before you.

In addition to the accounts of the 23 works examined, I have also examined the accounts of 10 foreign works; but I find their information is too incomplete and too difficult to bring to a basis of comparison with our English works, and I do not complicate my table by adding them in.

Of the 23 English works examined, 10—viz., those at Bournemouth, Chelmsford, City of London, Eastbourne, House-to-House (London), Metropolitan, Newcastle and District, Newcastle-on-Tyne, Leeds, and Exeter—distribute the bulk of their output on the converted alternating system. Two works—viz., those at Chelsea and Oxford—distribute on the converted continuous system. Eleven works—viz., Birmingham, Bradford, Brighton, Charing Cross and Strand, Hove, Kensington, Knightsbridge, Liverpool, Preston, St. James and Pall Mall, and Westminster—distribute on the direct system.

In Table VI. I have grouped these 23 works into these three systems of distribution, and have arranged them in each group in order, always heading the list by the works that uses the largest quantity of fuel. It is curious to remark that this system of grouping also divides them very fairly into the two great divisions of

1. Rope- or belt-driven plant.
2. Direct-driven plant.

In the first group I have averaged the fuel consumption in T.U. per watt-hour, omitting from the average the first-named works, as the conditions of working are somewhat abnormal; and, similarly, in the last group I have averaged the fuel consumption for the whole, with the sole exception of the first-named works —*i.e.*, Preston—the conditions in this case being also abnormal. These averages show that the consumption of fuel per unit sold in the first group is about 94 per cent. greater than in

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Table VI.—Comparison of Fuel Used.

Works.	Distinguishing Letter.	Cost of Fuel per Unit Sold.	B.Th.U. in Fuel Used per Watt-Hour.	Efficiency of Distribution.	B.Th.U. per Watt-Hour Generated.	Description of Plant.
CONVERTED ALTERNATING SYSTEM.				%		
Newcastle and District	A	0·8	310	70	218	Steam turbine.
Leeds	B	1·23	300	66	200	Alternators, rope-driven.
Bournemouth	C	1·81	232	69	160	„ „
House-to-House... ...	D	1·93	265	66	175	„ „
Newcastle-on-Tyne	E	0·64	262	66	173	„ „
Metropolitan	F	1·8	232	66	153	(1892) Mixed system.
Eastbourne	G	1·42	180	60·8	109	Alternators rope-driven.
Exeter...	H	1·35	135	66	89	„ „
Average of B, C,	D, E	, & F	245	...	161	
MIXED SYSTEM.						
City of London	I	1·24	172	82	141	Mixed system, driving.
Chelmsford	J	0·96	146	76	112	„ „
Average of I & J	...	...	159	...	126	
CONVERTED CONTINUOUS.						
Chelsea	K	1·11	142	...	...	Dynamos, driven direct.
Oxford	L	0·70	88·5	62	55	„ rope-driven.
Average of K & L	...	...	115	...	72	
DIRECT SYSTEM.						
Preston	M	1·65	315	93	255	Dynamos, driven direct by double-acting engines.
Liverpool	N	0 95	186	75	143	Dynamos, driven direct by single-acting engines.
Birmingham	O	0·88	183	75	140	„ „
Charing Cross & Strand	P	1·13	147	90	132	„ „
Hove	Q	1 26	147	82	120	„ „
St. James and Pall Mall	R	0·87	116	95·25	110	„ „
Bradford	S	0·66	119	88·7	110	„ „
Brighton	T	0·904	117	80	94	„ „
Kensington	U	0·87	116	86·5	100	„ „
Westminster	V	0·78	104	88	92	„ „
Knightsbridge	W	0·632	84	91·5	78	„ „
Average of N to W	...	...	133	...	112	
Ideal works	...	0·27	36·25	90	32·6	

Mr. Crompton. the direct group; but as this difference is made up very considerably by the difference in efficiency of distribution, I have calculated the actual fuel consumption at the terminals of the dynamo by the efficiency of distribution of the two systems, which I regret to say is in several cases an assumed figure, as in several cases it appears to be actually unknown to the works engineers themselves.

The table shows that, whereas the efficiency of distribution of the converted alternating systems is apparently somewhat under 66 per cent., with the direct systems (excluding the two-wire systems) it is about 86 per cent. The fuel used per unit generated in the converted alternating systems appears to be 43 per cent. higher than that used by the direct systems. In making these calculations I have carefully avoided considering those where a mixed system of distribution is used. The table also shows that the fuel average of the works where the alternators or dynamos are rope-driven is about 46 per cent. higher than where the dynamos are direct-driven by high-speed engines; and I think that the information that the table gives on this point is of the utmost importance, as it shows in a marked degree the economical advantages of high-speed direct-driven steam dynamos over slow-speed engines driving dynamos or alternators by ropes or belts.

I should here state that the preparation of Table VI. has been the principal cause why this paper has been delayed to such a late period of the session. The figures as printed in the proofs that you have in your hands have been altered several times, as additional information has been forwarded to me by the various engineers in charge. Even now I find that several mistakes and omissions exist. Some of them have been corrected on the large table on the wall, but those in your hand need correction as follows:—

The averages of the first group include all the works mentioned, with the exception of the Metropolitan and Exeter; the Metropolitan being for the year 1892, and the Exeter accounts being based on an estimated and not actually measured output.

Again, the efficiency of distribution of the Chelsea Company,

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hence the calculation per unit generated, ought to have been omitted; the figure given is that that would be obtained if the efficiency of distribution was the same as at Oxford. The Oxford figures came in at such a late period that I was unable to mention them in the body of the paper. The results are very encouraging; in fact, I think they are too good to be true, especially when we come to consider the corresponding use of stores in Table VII.

I have received a communication from Mr. Hunter, representing the Newcastle and District Company, in which he begs that I will make it clear that of the steam turbines used during the past year, only one was condensing; he also demurs to the figures I have given of 310 B.T.U. per watt, as he says the calorific value of the coal used at Newcastle was only 7,250, instead of 11,300, the figure assumed by me.

In explanation of my calculations I may say that I used the figure 11,300 as furnished to me by Mr. Jackson, of the Newcastle-on-Tyne Company; but I believe that even this figure is too low, and that good Newcastle slack, such as any commercial man would purchase for steam-raising purposes at Newcastle, has a value not less than 13,000. I use identically the same slack for my Chelmsford works, and pay for it a price that is not higher than is now paid by either of the Newcastle companies, and I find on actual test that it has a calorific value of 14,000; so that I cannot accept Mr. Hunter's explanation that the high fuel consumption at Newcastle is due to the inferior quality of the coal used.

I have also received a communication from the St. James and Pall Mall Company altering the figures originally given in Table VI., which were the 1892 figures; the alteration is also now entered on the table on the wall.

I must also say that I have not made any selection in the accounts entered in this table. I have taken all the accounts that were ready at the time I prepared the table, and those that are omitted were omitted solely at the request of the engineers in charge, on the grounds that the only figures available of 1892 did not represent the present state of affairs.

Mr. Crompton.

Eight years ago I stood almost alone when I recommended that the 1,200-H.P. load of the Vienna central station should be divided amongst eight steam dynamos coupled direct to high-speed engines, as at that time most engineers still believed that high economy in the use of steam could only be obtained by putting down long-stroke slow-speed engines such as are commonly used in cotton mills, and driving from these engines the dynamos by means of ropes or belts. This superstition was founded on the belief that steam could only be economically used in large engines of this type, which obtained their high piston speed by long strokes and few revolutions per minute; but it did not take long to show that the great variations of load in an electric supply works causes these huge engines to run for many hours at a very small fraction of their load, making them very uneconomical, so that the subdivision of their load between several smaller engines became necessary.

Mr. Willans, in his first and historic paper on steam engine economy read before the Institution of Civil Engineers, was the first to strike a blow at the erroneous belief that economy could only be obtained from long-stroke slowly revolving engines, by showing that as the enemy to economy, particularly in the smaller engines, is cylinder condensation, the true way to reduce this is not by mere piston speed, as was the current belief, but by reducing the time during which the cylinder surfaces are exposed to the cooling action of the exhaust or of the condenser previous to each fresh steam admission—in other words, by using rapidly revolving short-stroke engines instead of slowly revolving long-stroke ones. Once this was understood, it followed that the high-speed engine making many revolutions, and therefore best suited for coupling direct to our dynamos, is also theoretically the most economical in use of steam. That this is also true in practice is shown by the long series of experiments carried out by Mr. Willans, and the figures that I am now putting before you. The advantages of direct driving are obviously not confined to the Willans, or, indeed, to any single-acting, type of engine; in fact, we have now a considerable choice of high-speed engines, all of which can be coupled direct to dynamos, and which use their

steam economically. There is one advantage common to all direct-driven steam dynamos, *i.e.*, their high efficiency in $\frac{\text{E.H.P.}}{\text{I.H.P.}}$. This efficiency, which has been gradually creeping up from 80 per cent., which was the efficiency we obtained from the Vienna steam dynamos in 1886, to the very high figure of 88 per cent., which has recently been obtained by a Willans-Siemens combination, has been much commented upon, and has in some quarters met with actual disbelief; but all who know how accurately the tests have been carried out at Thames Ditton, and who have themselves made independent check tests, know also that such an efficiency can be obtained without difficulty—in fact, that efficiencies in excess of 86 per cent. can now be guaranteed at full loads, and 80 per cent. at half loads. Mr Crompton.

The case is far different with rope- or belt-driven sets. In most cases it is difficult to obtain an efficiency of 78 per cent. at full load and 70 per cent. at half load when the engines are fitted with the ordinary unbalanced slide valve, or 80 per cent. at full load and 73 per cent. at half load when the engines have Corliss or balance valves. I must, however, note that Mr. Parker, in his paper—read before the Institution of Civil Engineers—on the Liverpool Overhead Railway, gives us the satisfactory results obtained from slow-running horizontal engines driving dynamos by ropes; but, although I do not challenge Mr. Parker's ultimate figures, yet I think that without doubt he has made a mistake in his calculated efficiency—that is to say, $\frac{\text{E.H.P.}}{\text{I.H.P.}}$. I think that it would be difficult for me—or, in fact, for anyone who has paid much attention to the losses due to the friction of steam engines, and particularly of condensing engines, and to the losses occasioned by rope driving—to accept Mr. Parker's figures. No one has made more careful experiments on the friction of such engines than Messrs. Sulzer, of Winterthur, and Messrs. Carels Frère, of Ghent, who make the same type of engines. I have been informed by the latter that an engine efficiency of 91 per cent. is only rarely obtained; generally the efficiency is somewhat

Mr. Crompton.

lower. Mr. Parker states that the electrical efficiency of his dynamos is 97·7 per cent., which is an extremely high figure. If we take the commercial dynamo efficiency at 96 per cent., which is an outside figure when we consider the side strains on the bearings caused by the rope driving, and if we suppose that the loss due to the rope driving is only 2 per cent., which I believe is less than has ever been noticed, it is just possible, with a 91 per cent. engine, a 2 per cent. rope loss, and a 96 per cent. dynamo, to get 85·6 per cent. efficiency.

Although I do not believe that such an efficiency, and correspondingly small consumption of steam per E.H.P. at full and half loads, can be obtained in practice by engines driving dynamos by ropes, yet it is so often attained by direct-driven sets that at least one maker can now guarantee figures very closely approaching the ideal figures I have given of 18½ lbs. of steam per unit at full load and 21½ lbs. at half load. Yet in the cases of direct driving such high efficiency is easily accounted for. In the first place, the engines are fitted with piston valves, which are the most perfect form of balanced valves; hence the internal friction of the Willans or Chandler engines, running as they do with all their parts thoroughly bathed in oil, must be probably lower than that of any other type of engine. Moreover, with direct driving there is no side strain whatever on the dynamo bearings; and even the downward pressure on these bearings can be partially eased by so placing the armature core in relation to the bore of the magnets that a certain amount of lift is given to the core at the time that the magnets are excited. Under such conditions it will be seen that the engine and dynamo mechanical friction can be reduced to a minimum—in fact, to a point very far below what is possible when any form of rope or belt driving is used. The figures that I now give show that the best results yet obtained have been with Willans engines driving direct-current dynamos; and I believe this is mainly due to the great reduction of friction which I have just mentioned, and which tells heavily in favour of this class of steam dynamo when it is only partially loaded. Hence we find that, whereas the combined efficiency of a Willans combination is as high as

80 per cent. at outputs as low as two-thirds full load, the combined efficiency at two-thirds load of a slide-valve engine driving a dynamo by belts or ropes rarely exceeds 70 per cent.; and unfortunately, however much we may desire to keep the load-factor of the engine above 66 per cent., or two-thirds, yet under existing circumstances it is a matter of difficulty to do so even in works where accumulators are used, and in works where there are no accumulators with all converted systems the average engine load-factor appears to be far below this.

Mr. Crompton.

As you no doubt expect me to express an opinion as to the cause of the wide differences in economies of fuel shown in these comparative tables, I must point out that, even if we exclude the difference in distribution efficiency by making the allowances that I have done, there still remain three sources of loss—one already dealt with under the heading of the boilers, and the second due to the engines, dynamos, or alternators, and the third to losses which have been called by Kennedy "obscure works "losses." Now I think the main cause of the difference in engine and dynamo losses lies in the fact that in the works under consideration the engines have been driven at widely differing load-factors; and, as whenever the engine load-factor is low the use of steam is correspondingly high, I think that this question of engine load-factor is of supreme importance. As I have shown above, a low engine load-factor tells more against belt- or rope-driving sets than against direct-driving ones; but in neither case has the subject received the attention that it deserves. Every facility should be given for the men in charge of the steam dynamos to ascertain for themselves at any time at what load-factor they are driving their plant, and if this were done more frequently I am sure that great improvements would result. One reason why at present the men in the supply stations know so little about this question is, that in most cases it is only looked into as a sort of holy mystery by the engineering staff, and at long intervals of time; whereas I feel strongly a book ought to be kept in every works, and the men in charge should always enter up the load-factor of each engine during the hours the stop valve is open; and in order that this may be done with a minimum of labour, I

Mr. Crompton. have devised and used in our Chelmsford works a system which I will here describe for the benefit of those who care to adopt it.

Diagram A before you has its base line marked off in percentages of the load of the engine; and the same line is, in addition, marked with the steam chest pressures, corresponding to these different percentages of load. This steam chest pressure can be noted by a carefully calibrated gauge fixed on the steam chest of the engine, the calibration being carried out as each set of indicator diagrams and electric load readings are taken; the result being that the man in charge of the engine can see at a glance from these steam gauges what ought to be the indicated and corresponding E.H.P. that his engine is giving, and from the same diagram he is able to calculate the consumption of pounds of steam per hour.

Opposite to each gauge pressure is entered the theoretical consumption of steam per horse-power per hour at the standard speed, ascertained from Mr. Willans's table. Thus, if the man in charge enters up these steam pressures of all the running engines every quarter of an hour, it is easy to prepare an accurate report on the engine load-factor of the day, and thus compare the calculated with the actual steam used during the run; so that men who habitually underwork their engines can be thus noted and reprimanded.

Of course I know from experience how much more difficult it is to work engines driving alternators at a high load-factor than is the case with continuous-current steam dynamos. This is partly caused by the comparative difficulty and complication involved in parallelising alternators, compared with the ease of throwing continuous dynamos in and out of parallel on a storage system. In the latter case the enginemen have only one order to observe—viz., to keep their engines as fully loaded as possible on a rising load, not to start an additional set until the sets previously running are considerably overloaded, and on a falling load to shut down the sets at the earliest possible moment, even if it leaves the remaining sets somewhat overloaded for some time. Unless such orders are given and carried out to the letter, so that engine load-factors exceeding 70 per cent. on the average

are obtained, it is useless to expect to reduce the consumption of steam below 50 lbs. per unit generated. Mr. Crompton.

The other causes of waste of steam in electric supply works are those which Professor Kennedy, in his lecture at the Royal Institution, speaks of as "losses about which we engineers feel "very sore, and which sometimes try our temper and our patience "greatly, and are not recognised as having any kind of respect- "able existence." These are those connected with leaks from boiler fittings and steam pipes, with condensation losses in the steam pipes, and due to the wasteful use of steam by all present known means of boiler feed.

These losses have been ignored by engineers, and have never received the attention they deserve; but, as they continue throughout the 24 hours, they amount to a very considerable percentage of the steam evaporated by the boilers, and of course tell most during the summer months, or, in fact, in any works where the load-factor is low. Engineers who have been most successful in dealing with these difficulties, and have minimised these losses to the greatest extent, are those who previous to entering electrical works have received a practical engine-room training, either as sea-going engineers, or in engine rooms of a similar class where fuel economy has been persistently studied. I believe the best remedy for the pipe condensation losses will lie in the direction of superheating the steam after it leaves the boilers. If we could superheat the steam so as not only to have no pipe condensation at all, but to deliver the steam to the engine cylinders at a temperature 8 or 10 per cent. above the corresponding temperature for saturated steam, I believe that we should at once save nearly 10 per cent. of the steam that we now have to evaporate in our boilers. It is very easy to talk of superheating steam. In the days of low-pressure steam at 15 lbs. pressure such superheating was a reasonably easy matter; but the case is widely different when the high-pressure steam leaves the boiler at a temperature of 375°, as is now the case. Any further superheating is very much in the nature of passing this steam through pipes at a temperature which nearly amounts to red heat, so that it is little wonder that

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not many engineers have cared about tackling such a difficult and risky problem; but it is quite certain that this problem will be tackled, and I have recently heard that it has been satisfactorily dealt with by Messrs. McPhail & Simpson, the superheater consisting of a large number of bent tubes made of thick lap-welded iron, each tube being only about 1 inch diameter. The bent portions of these tubes are so placed that they are exposed to the hot gases when they first pass through the flues of the boiler, such as the space at the end of a Lancashire or of an "Economic" boiler; in the case of the Babcock boiler it would be more difficult to find a place for them. It is evident that whoever attempts to deal with this problem of working out a satisfactory superheater will have a great many difficulties to deal with. The superheater must, as I have said, be placed so as to be exposed to the high-temperature gases, and yet it must be accessible for ready replacing of the tubes and for repairs. Moreover, it must be easily put in and out of circuit, so that a failure of one of the tubes should not in any way cripple the steam supply of the works. These requirements are in a sense contradictory, but I have no doubt, now so many minds are directed to this problem, it will be successfully dealt with.

Another point which is receiving the attention of all of us is the extended application of condensing plant.

In situations where condensing water is available this problem presents no difficulty, but in a large number of cases condensing water is not available; and of late years—in fact, dating from the time of my 1891 paper—a number of proposals have been made to introduce what are called evaporative or surface condensers, which may be described as consisting of a very extended surface of tubes through which the steam passes, the tubes being cooled externally partly by an air-fan blast, and partly by a limited supply of water trickling on to the outside of them. Of course, so long as the amount of water used is equal to the feed water used, there would be no advantage in using such a condenser, other than that the steam consumption may possibly be economised, especially at times of light load, so that the steam that is required to pass through the condenser would be proportionately reduced; but

Mr. Ledward and several other gentlemen who have paid attention to this subject are confident that they will be able to eventually reduce the cooling water required to two-thirds of that of the ordinary feed water; and if this is the case, it will result in a very great advantage, not only in removing the nuisance—which some people insist is a real nuisance—of the steam issuing from the chimneys of the various supply works, but the difficulties with the boilers will be also greatly diminished. But it must be recollected that this use of condensing water entails the working out of several very difficult problems connected with the thorough filtering out of the oil contained in the exhaust steam before it is allowed to re-enter the boilers. The united opinion of nearly all boiler engineers and inspectors is to the effect that if the water contains the smallest percentage of carbonate of lime the entry of even minute quantities of oil into the boiler is likely to have disastrous effects. The oils forms with the carbonate of lime a covering to the flues and tubes of a highly non-conducting nature, which allows the iron or steel plates or tubes to be greatly overheated, and great damage is thus done; so that most boiler insurance companies absolutely forbid the returning of condensed water to the boiler unless it has previously passed through a purifying apparatus which absolutely frees it from the oil. Mr. Crompton.

I have briefly mentioned how very considerably the wasteful nature of the steam pumps that are at present available for boiler feed pumps affects the total economy of the works. For some time past at Chelmsford I have attempted to deal with this difficulty by supplying my boilers with feed pumps electrically driven; and although these electrically driven feed pumps are by no means as efficient as I hope to make them in the future, yet in their present state their use shows a marked economy over the Worthington or other direct-acting pumps that were previously employed. The electrically driven pumps use the energy from the main switch-board, which is generated in an economical manner; whereas the direct-driven pumps are driven not so much by steam as by water condensed in their steam pipes. I have over and over again called the attention of pump makers to the great want there is of a more economical steam pump than is at

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present in the market; but there appears to be a difficulty in dealing with the question, I believe chiefly owing to the intermittent way in which these feed pumps are worked, so that between periods of working their supply steam pipes get comparatively cooled.

I have spoken of the difficulty I have met with in obtaining trustworthy figures as regards water consumption. This is mainly due to the fact that a thoroughly trustworthy water meter is not an easy article to meet with. In order that such a water meter may accurately record the water fed into the boiler, it ought to be placed between the feed water heater and the boiler, so that any leakages that may occur at the pumps themselves, or in the lines of pipes, or in the feed water heater itself, may not affect the question of boiler evaporation. This necessarily means that such a water meter must pass hot water. For several years past I have been using Schönheyder's meter in this position, with fairly satisfactory results, but in its present state it leaves much to be desired. The pins wear to such an extent that in our Chelmsford case we find it necessary to take the meter out and replace the pins and recalibrate it once every three or four months. The calibration of such a meter is not a difficult matter if the feed water in any part of its course passes through a rectangular tank, the cubic contents of which can be readily measured, and the water contained marked for each inch of height.

When speaking of the differences which exist between the calculated consumption of fuel and water by the plant when tested under full load and that which is observed from the water and coal bills in the month's or year's working, I was at one time doubtful whether any single 24-hour test would include within it the observed losses; but during the past year, having made a large number of such 24-hour tests at our Chelmsford works, I have come to the conclusion that such 24-hour tests which follow a complete cycle of the working are a fairly trustworthy guide to the annual losses; and I cannot too highly recommend the practice of taking such tests, and of showing them graphically in the manner universally adopted by mechanical engineers, and shown by Professor Kennedy in the discussion which followed on

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my paper in 1891. Diagram B shows the way in which we plot a 24-hour test at Chelmsford, and this may be applied to any other works. Many of you will ask how I have been able to obtain the electrical work at the terminals of the dynamo in the case of the Chelmsford works, where we use alternating dynamos. My answer is, that it is only during the last few months that I have been able to do this; and it is owing to the extreme kindness of Professor Fleming, and his unwearied attention in perfecting the Mengarini wattmeter for our purpose, that we have been able to obtain a daily record of the electrical energy generated by our alternating plant, as well as that generated by our direct plant. Diagram D shows an enlarged diagram obtained from this wattmeter, and we have divided it up into known portions of the load from cards taken on other nights. We are able to separate the load in the town shops from the load in private houses owing to the fact that it is the custom at Chelmsford on Wednesday night to close all the shops, so that our load on that night consists entirely of the public lighting, which is an ascertained and invariable quantity, on which is superposed the lighting in the private houses only.

It will be interesting to many here to know that the circumstances under which we work at Chelmsford of supplying the light between certain hours has enabled us to greatly cut down the transformer loss, so that we have been able to show an efficiency of distribution reaching 76 per cent., which I believe is probably as high as has ever been reached with alternating plant; but if we were compelled to keep the supply up through the remainder of the 24 hours, I am afraid the state of affairs

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Diagram C shows what I call a clinometrical method of showing a boiler trial. The lines radiating from the lower left-hand corner of the diagram present rates of evaporation in lbs. of water per lb. of coal, and the rate of efficiency at which the boiler is working at any part of the trial may be instantaneously judged by the eye by noting to which of the radial lines the black chart line is parallel. It will be seen that the black chart line falls for nearly the whole of its length between the lines 7 and 8; but if we take successive portions of it, it will be seen that at the commencement the rate corresponds fairly to the mean rate, but from 4 to 5 it rose until the rate was nearly 10 lbs.; from 5 to 6 it was even higher than this; it then fell until between 8 and 9 it was as low as 4 lbs.; between 10 and 12 the rate was at the average.

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would be widely different. We are also aided by such a large part of our load being public lighting, which goes on throughout the entire hours of darkness in summer and in winter.

FUEL AND WATER.—PART III.

Effects of Distribution Efficiency.

I am obliged to introduce this question into this paper, as there can be no doubt that the high consumption of fuel shown by certain works is partly due to low distribution efficiency; but I do not propose to dwell on this highly important question, which merits a paper to itself, besides being of a highly controversial character. I find that in few cases have the engineers of supply works had the pluck to face this important problem, and to ascertain and state boldly what distribution efficiency they have noted. In several cases, however, this has been done, so that I am able to make the Table VI. reasonably complete. From it you will see that the efficiency of distribution of direct systems, including meter losses, varies between 85 and 91½ per cent., whereas that of converted systems varies between 60 and 82 per cent.; the higher figure being only found where the system of switching transformers in and out of circuit is practised. In the very small loss of from 10 to 12 per cent. observed in the direct systems are included all those due to the accumulators, to the $C^2 R$ losses in the mains, to leakage, and to meters failing to register; and I do not think it is likely in the future we shall be able to improve much, if at all, on this distribution efficiency—in fact, we are assured by our American friends that it would pay us better to somewhat reduce this efficiency by putting less copper in our mains; but we consider that our English practice is right, as in order to get thoroughly steady lighting and good regulation it is necessary to work at this high efficiency, and at the present price of copper it can be easily shown that it pays to do so.

STORES, WATER, LABOUR, AND SUPERINTENDENCE.

Under the head of "Stores used in the Generating Works" are

usually included water (which in London and many other towns has to be paid for), oil, grease, waste, packing, gauge glasses, and other materials which are from day to day used in the working of a supply works. The decrease in the stores item in several of the companies has been very noticeable during the last few years of working. In the case of the Kensington Court works of the Kensington Company, the stores have in some months reached as low a figure as 0·025d. per unit sold, and there is no doubt that even a lower figure will be reached as the output and load-factor improve. In this question of use of stores the closed type of engine, such as those made by Messrs. Willans, Bumsted & Chandler, and Belliss, of Birmingham, compare most favourably with the open type of engines. During a visit paid to Vienna two years ago, I was told by Mr. Melhuish, the engineer in charge of the Imperial Continental Gas Association, that the consumption of oil by an open-type compound engine which they had recently erected in that station was 16 times as great as the consumption of oil by a Willans engine of equal power; and I think that in many cases differences almost as great as this will be observed between the two types of engines. When it is considered that in the close type the only glands there are to pack are those of the governor gland and at the two ends of the crank shaft, whereas in a compound or triple open-type engine there are certainly not less than eight important glands to pack, and not less than 20 oiling points requiring separate attention, it will be seen how great the difference is. In the case of rope-driving sets there are in most cases three dynamo bearings to be oiled instead of the one bearing in the case of the direct-driven set, and the side strain on the bearings necessitates nearly a fivefold use of oil. Mr. Crompton

Table VII. gives the cost of stores in the same works as Table III., from which it will be seen that, whereas some of the works using direct-driven plant have already come within a measurable distance of the figure of 0·03d. for water and petty stores, those using belt- or rope-driven sets are a very long way from it.

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Table VII.—Comparison of Stores, Wages, and Superintendence Costs.

Works.	Distinguishing Letter.	Stores and Water.	Labour and Superintendence.	Description of Plant.
CONVERTED ALTERNATING SYSTEM.				
Newcastle and District ...	A	0·27	0·83	Steam turbine.
Leeds	B	0·21	1·37	Alternators, rope-driven.
Bournemouth	C	0·27	1·24	,, ,,
House-to-House	D	0·41	1·25	,, ,,
Newcastle-on-Tyne ...	E	0·163	0·72	,, ,,
Metropolitan	F	0·24	0·75	Mixed system.
Eastbourne	G	0·14	1·4	Alternators, rope-driven.
Exeter	H	...	...	,, ,,
Average	...	0·24	1·19	
MIXED SYSTEM.				
City of London	I	0·23	0·91	Mixed system, driving.
Chelmsford	J	0·16	0·94	,, ,,
CONVERTED CONTINUOUS.				
Chelsea	K	0·34	0·77	Dynamos, driven direct.
Oxford	L	0·045	1·24	,, rope-driven.
DIRECT SYSTEM.				
Preston	M	0·45	1·35	Dynamos, driven direct by double-acting engines.
Liverpool	N	0·15	0·37	Dynamos, driven direct by single-acting engines.
Birmingham	O	0·17	0·82	,, ,,
Charing Cross and Strand	P	0·185	0·61	,, ,,
Hove	Q	0·2	1·44	,, ,,
St. James and Pall Mall	R	0·139	0·69	,, ,,
Bradford	S	0·094	0·81	,, ,,
Brighton	T	0·162	0 96	,, ,
Kensington	U	0·15	0 61	,, ,,
Westminster	V	0·19	0·95	,, ,,
Knightsbridge	W	0·17	0·60	,, ,,
Average	...	0·15	0·72	
Ideal works... ...	N to Q S to W	0·03	0·2	

Items 4 and 5, Wages and Superintendence in Works. Mr. Crompton.

On Table VII. I also give these two items for all of the works, showing a somewhat slow progress towards my ideal figure of 0·2d. per unit. This table shows that the lowest figure yet reached is 0·38d. per unit; but, as this figure is very largely a question of output, it is certain that from the increase of output alone, and without the introduction of any refinements having for their object the reduction of the staff employed in the stations, the wages and superintendence charge may be easily brought down. It is evident, however, that this charge must be much higher in the case of belt- or rope-driven machinery than is the case with direct driving, and Table VII. shows this to a very marked extent. There is every reason to believe that with direct-driving closed-type engines 1,000 kilowatts will demand the services of only one attendant, whereas it is doubtful whether with rope- or belt-driven and open engines one man could attend properly to more than 600 kilowatts of plant. This, however, is only my opinion, as in neither case has the output of any existing works been sufficiently large to enable the attendants to have their time occupied in the most profitable manner; it is quite certain, however, that under present conditions the use of accumulator storage has a most important effect on reducing the cost of attendance. Whether this will be so in the future, when the all-night loads begin to be heavy, I am at present not able to say, but I hold a very strong opinion that a proper proportion of accumulator storage will even in large stations reduce the cost of attendance at least 30 per cent., and in smaller stations from 40 to 50 per cent.

Maintenance.

I have considered this part of the subject with considerable care. It is the one point on which existing opinions vary through very wide limits, and, as far as I can judge, opinions incline at present in what I believe to be an unsafe direction; that is to say, too much has been made of the extremely light cost of repairs of existing works during the few years that they have been running, and figures have been founded on this which I am afraid will turn

Mr. Crompton. out to be altogether illusory. In all other businesses the upkeep of boilers which require to be periodically fired up and cooled down, and which have to be heavily fired at times of maximum load, is put down at a figure varying from 5 to 10 per cent. on the original cost of the boilers. The upkeep of steam engines when worked at a far easier rate than is usual in electric supply works is usually taken at from 3 to 5 per cent. on their first cost; whereas the published accounts show that nothing like these figures have hitherto been spent on, or put aside for, the maintenance of these parts of the plant. I do not think that any accurate estimates can be formed of the ultimate cost of maintaining electric generating and distributing plant, other than on a percentage basis such as I have introduced in both my previous papers.

I have therefore prepared Table VIII. to show what has been my own experience in this matter. This table gives the actual sum spent on the maintenance of various parts of the plant of the works of the Kensington and Knightsbridge Company during the last four years out of the seven years that this company has been supplying electrical energy. I have given in the table the original cost of each part of the plant, and have worked out the annual percentage cost which the maintenance bears to the original cost. As some of the steam engines and boilers of this company have been at work seven years, and the bulk of the plant has been at work five years, sufficient time has elapsed for the maintenance cost to have settled down to the figure at which it is likely permanently to remain. As might be expected, the upkeep of the boilers and the accumulators has been more costly than that of any other portion of the plant, but in neither case is the amount as high as I expected it would be. The noticeable feature is the very small sum spent on the upkeep of the engines, of the dynamos, and of the mains.

The cost of upkeep of the engines is confined to the substitution of small parts as they wear, by new parts supplied from store. It will be seen that the upkeep of the dynamos is almost *nil;* but I must direct particular attention to the small sum spent on the inspection and maintenance of the mains, as

this vindicates my often-repeated assertions that a well designed and conducted bare copper system must cost less to inspect and maintain than any system of continuously insulated cables. At any rate, the sum expended on mains as shown in this table is an outside sum, as it includes many alteration items which can hardly be considered as fair wear and tear, but rather in the nature of improvements, and thus chargeable to capital. Mr. Crompton.

Table VIII.—Cost of Maintenance of Works for a Period of Four Years—1890, 1891, 1892, 1893.

Description of Plant.	Original Cost.	Spent on Maintenance in Four Years.	Per Cent. per Annum on Cost.
	£	£	%
Buildings	16,598	429	0·65
Boilers	8,124	1,704	5·23
Engines	9,900	704	1·77
Dynamos	8,660	264	0·76
Other plant	12,868	968	1·9
Accumulators ...	15,115	1,968	3·25
Mains and services	65,167	952	0·36
Meters	6,549	628	2·5
Total ...	£142,981	£7,616	1·35%

The maintenance sum spent by this company has been sufficient to keep the plant in absolutely as good order as when it was first put down, and, as I have just said, in some cases has enabled improvements to be introduced which have been charged to revenue. This gives me hopes that future experience will not show any marked increase in these percentage rates, but rather the reverse; so that the ideal figure I have proposed of 0·4d. per unit, which on 5,000,000 units will yield the very respectable sum of £8,300 per annum, will be a sufficient sum to maintain the entire plant in perfect working order for ever.

I have now taken you through all the items of cost of an electrical supply works, and have endeavoured, as far as possible, to compare what has been done up to date with an ideal possible standard. Whether this standard be ever reached or no, I think

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it will serve the useful purpose of holding before you a goal which we may all strive to attain, and that without the necessity for bringing out any wonderful revolutions in our practice, or, in fact, doing anything but intelligently perfect and use our present appliances.

I hope my efforts in preparing this paper will be appreciated by those to whom it is addressed. I personally have the warmest sympathy with and admiration for the work of the large number of young electrical engineers who are now scattered over the various supply works, and to whose efforts we are indebted for the very marked advance in economy that I have this evening brought before you. I sincerely hope and trust that the means I have adopted of circulating the paper before the meeting will have given time to these works engineers to appreciate some of my points, so that we may have the advantage of having the important questions that I have raised, ventilated and discussed by those who are most competent to do it, namely, the resident engineers of electrical supply works.

I cannot conclude this paper without expressing my thanks to the very large number of gentlemen who have assisted me in my labours. In order to get together the data necessary for the production of this paper, I have had to visit a number of stations, and write a large number of letters to the engineers of stations which I could not visit. As it may be the wish of many of these gentlemen to preserve their anonymity, I do not thank them by name. As regards stations with which I personally am closely connected, the importance of anonymity is not so great, and I have therefore the pleasure in stating that much of the splendid results that have been obtained from some of my own stations—the figures of which no doubt some of you have recognised in the tables before you this evening - are due to the continued hard and intelligent work of Mr. Miller, the resident engineer at Kensington, Mr. Barley, the resident engineer at Knightsbridge, and Mr. Pott, the resident engineer at Chelmsford.

In conclusion, the art of electrical supply has now passed from the stage of estimate and talk into that of commercial enterprise. What is to be learnt from the tabulated results of commercial

enterprise I have endeavoured to bring before you, with the main object of showing what are the possibilities of cheapening electrical supply in the immediate future, as I feel strongly that, if we electrical engineers are to play our part in making this an electrical age, the electrical supply must be so carried on that the poorest can avail themselves of it as well as their richer neighbours. Once this is done, many of the problems of electrical supply will be simplified. I think most engineers will agree that it is a far easier and more satisfactory matter to supply electricity to small consumers than to large ones; and it is certain that when electrical supply can be extended to small tenements, it will have a very powerful influence in increasing the material comfort of the poor. In fact, I may say that until electric supply becomes general I consider we have only touched the fringe of our task. Mr. Crompton.

I say this because I think it quite possible that some of my critics will divert the discussion into side issues. I hope I have made it clear, however, that it is only by careful study of the wider problems connected with economical use of fuel, economical use of steam, and economy in maintenance, that such future cheapening is to be looked for.

Mr. J. S. RAWORTH: I imagine, Sir, that this is the most comprehensive paper upon the question of costs and maintenance of works that has ever been laid before this Institution. I have read it carefully through from one end to the other, but very far from digested it. In fact, it seems to me to include very nearly the whole education of an electrical engineer; and it will be a very long time before we have all of us put it into actual practice in the way of obtaining the ideal which Mr. Crompton has so obligingly and ably laid before us. I find, Sir, in this paper only two lines that are absolutely superfluous: those are the lines in which Mr. Crompton expresses a hope that his efforts to put these figures and facts before us will be appreciated by this Institution. On what occasion did Mr. Crompton ever speak to this Institution without being appreciated? Mr. Crompton always gets our attention—firstly, because he is one of our most eminent engineers, but principally because he is such a magnificent sportsman. Mr. Mr. Raworth.

Mr. Raworth.

Crompton is never satisfied with writing a paper and saying to himself, "This is a paper which everybody will agree with, and "everybody admire;" but he spots it all over with little pin-points. He puts a little bit of a curl on the point of a diagram, and says, "That will fetch Kapp! If it does not fetch him, it will "fetch Dr. Thompson!" And then he squirls in a little about alternating currents, and says, "That will fetch Mordey, or, if not "him, Raworth!" On this occasion I have begun first; but I have no doubt the others will follow fast enough afterwards. Now I find, Sir, there are various points to-night in which I take a very great interest. Mr. Crompton has never spoken to the Institution on the question of engines or boilers without my either disagreeing with him or giving him some advice. I find it a very pleasant task to be able to notice to-night that he has taken some of the advice I gave him on a former occasion—viz., to throw up Lancashire boilers in favour of Babcock boilers. But, without going into details at the present moment, I should like to look at the broad points of the paper, which are really the most interesting points; and that is, his endeavour to show the possibility of reducing the cost of electricity to 3d. per unit to the consumer. He arrives at the figures he gives us by first of all trying to reduce the capital; secondly, by increasing the output, and, thirdly, by using better engines, boilers, and dynamos. At first I thought the figure of 2s. capital expenditure per unit sold per annum was scarcely justified; but, on looking into the matter, I find Mr. Crompton was perfectly justified in putting that figure before us, for at Bradford and at Newcastle they already deliver 8 units per sovereign of capital expended. The next best on the list is St. James's, 6 units, and St. Pancras, 5 units per pound of capital expended. Then we come to Bournemouth, Westminster, and Charing Cross, who deliver 4½ units per pound of capital expended; the Metropolitan, Kensington, and Liverpool give 4; and last of all come Preston and Oxford, 2. Of course it would be unfair to attempt to apply the moral of these figures, because the circumstances are so remarkably various; but Oxford, which I believe is set up as a perfect system, appears to cost rather too much to be likely to pay a dividend to its share-

holders. One very important point Mr. Crompton has conceded to us in this paper is in connection with coal. You probably are aware that some year or two back Mr. Crompton put forward a table in which he corrected all the prices per unit for coal expenditure by sifting them out in terms of their respective values in British thermal units, and bringing them all up to one level, and showing what the cost for coal would be in each station if the coal values were so corrected. I then pointed out that the hydrogen was practically of no use. Although it counted in the table, it did not count in the boiler. I see now Mr. Crompton has fallen in entirely with my view. With regard to the boiler question, it is only of late years that we have had the great advantage of having accurate tests carried out by Professor Kennedy and one or two others in whom everybody puts the greatest reliance. My connection with the Babcock boiler goes very much further back than that. The first time I saw one was in a shop window, behind a piece of plate glass, in Manchester, somewhere about 1880 or 1881; and when I saw it I said, "That is the boiler for my money!" and I have never bought any other boiler since, except under compulsion. I can say perfectly honestly that these boilers have given me most perfect satisfaction from that day to this. I think, taking all the boilers I have put down since that date together, they represent considerably more than half the Babcock boilers that have been sold in this country; and, with the exception of one boiler, where from some extraordinary cause, never accounted for, three tubes burnt out closely following one another, I have never had any serious trouble whatever. I quite agree with Mr. Crompton when he states that, contrary to what every boiler maker tells us, Babcock-Wilcox boilers do not give wet steam. It is one of the calumnies that is constantly put before engineers and users that, whatever beautiful features the Babcock boilers may have, they give wet steam; and that, of course, in the eyes of the people who have to work electric lighting plants, is a very bad fault indeed. I wish to refer for one moment to the question of engine efficiency, upon which Mr. Crompton puts such very great stress; and I agree with him that Mr. Raworth.

Mr. Raworth.

it is a matter of the very first importance that the indicated H.P. we get in the engine should be transmitted to the dynamo, and given out in units the maximum possible. Mr. Crompton was one of the first to put the theory of direct coupling into practice, and we owe him very great credit for the initiative, and for the example that he has set us in that direction. I can assure Mr. Crompton that we who have to build alternating-current plant would have followed his example long since if it had been possible; but in the early days of the alternating-current industry we could not get the money to do it; and, in the next place, we did not see our way to do it, because, as you all know, you cannot run an alternator at any speed you like. You have to run it at a speed which is in accordance with the periodicity of the system you have chosen; therefore we had to find some other means of driving, and we took to rope driving, which has been pretty generally adopted. But we found that the sooner we could get rid of the ropes the better, because they were losing us 6 per cent. all the time they were running—not 6 per cent. on the load only, but 6 per cent. as a solid loss. Therefore, as soon as we could see our way to do it, we abandoned the rope driving and came on to the direct driving; and if Mr. Crompton will give us further statistics on this subject at some other time, I hope the alternating-current plant figures will come out better than they have done now, because the generally accepted method of rope driving will have disappeared to a very great extent, and direct driving will have taken its place. Then we come to the engine loss. Mr. Crompton is a very great admirer of the Willans engine, and very rightly so: it has stood the engineer in very great stead, and I admire it very much indeed; but when he says it is particularly efficient from the point of view of mechanics he is under a wrong impression. I know perfectly well the efficiency obtained is 89½ or 90 per cent., which is a very good efficiency; but it is owing to the fact that makers of ordinary vertical double-acting engines have not been in the habit of testing the efficiency of their engines that the idea arose in people's mind that the efficiency claimed by Willans & Robinson was the top efficiency.

Mr. Raworth.

Now I can get, and anybody can get, from an ordinary vertical double-acting engine 92 per cent. They can easily get it with no trouble whatever. You need not make any special arrangements. Of course, if your piston rings are too tight, you cannot get it; but if you follow the ordinary rules of engine designing by putting the engine bearings close together, thus doing away with the necessity of making the crank shaft too large, and if you do not use large unbalanced slide valves and too tight pistons, you will get 92 per cent. efficiency right off, without the slightest trouble in the world. The reason why the idea has grown up that Willans's engine is more efficient than ordinary engines, is that those ordinary engines that have gone through accurate tests have usually been horizontal engines, and in such cases you find this very objectionable mechanical feature: you find two pistons weighing perhaps each a ton, and you have to drag these heavy bodies of iron backwards and forwards on the bottom of the cylinders at the rate of 500 or 600 feet a minute, without any wheels on them. That is the reason why the Willans engine is so much more efficient than ordinary horizontal engines. But I wish to point out the Willans engine is extremely efficient on the down stroke; it is only on the up stroke it loses its efficiency, because when the piston is going back and doing no work it has to overcome the same frictional resistance as on the down stroke. Therefore, if you could retain all the advantages it now has, and make it double-acting, the probability is its efficiency would go up to 95 per cent. I must point out, with regard to the figures relating to the efficiency of distribution which Mr. Crompton has given us, where they refer to alternate-current systems he has fallen into a serious error. I will leave it to our experts to define the exact amount of the error; but it is important to note that in the central stations the engineers simply take the amperes multiplied by the volts as their output. As a matter of fact, the real output is less than this by probably 12 per cent.; so, if the figures were corrected by using accurate wattmeters, the efficiencies of distribution given in the paper would rise to much higher values. Another point is that the alternating-current system is used in

Mr. Raworth.

districts which are not comparable with the districts where they use continuous currents. Take Bournemouth, for instance, which has miles upon miles of wires in all directions—in fact, you can scarcely see from one house to the next where they use electric light—and compare it with the electric light in St. James's, where distribution is not more difficult than in a large hotel. So you see that, although these figures are very valuable, unless you have a great deal of local knowledge as to the conditions existing in each case, it is almost impossible to form a perfectly accurate conclusion.

But, Sir, Mr. Crompton does something for this Institution that nobody else does for it. We have a good many professors and mathematicians and paper readers, but we have only one prophet. We have only one man amongst us who will ever run the risk of exposing himself to the obloquy of his prophecies not coming true. He knows when he makes them that he runs that risk, and although many of his prophecies are fulfilled, to his great credit and renown, yet occasionally some of them do not turn out correct; and I think, when we have a prophet amongst us who will undertake such risks for the benefit of his more short-sighted brethren, we ought to give him the highest honours that this Institution can bestow.

The CHAIRMAN: Time will not permit of our continuing the discussion on this important paper any further this evening, and it must therefore be adjourned until our next meeting on the 10th May.

I have to announce that the scrutineers report the following candidates to have been duly elected:—

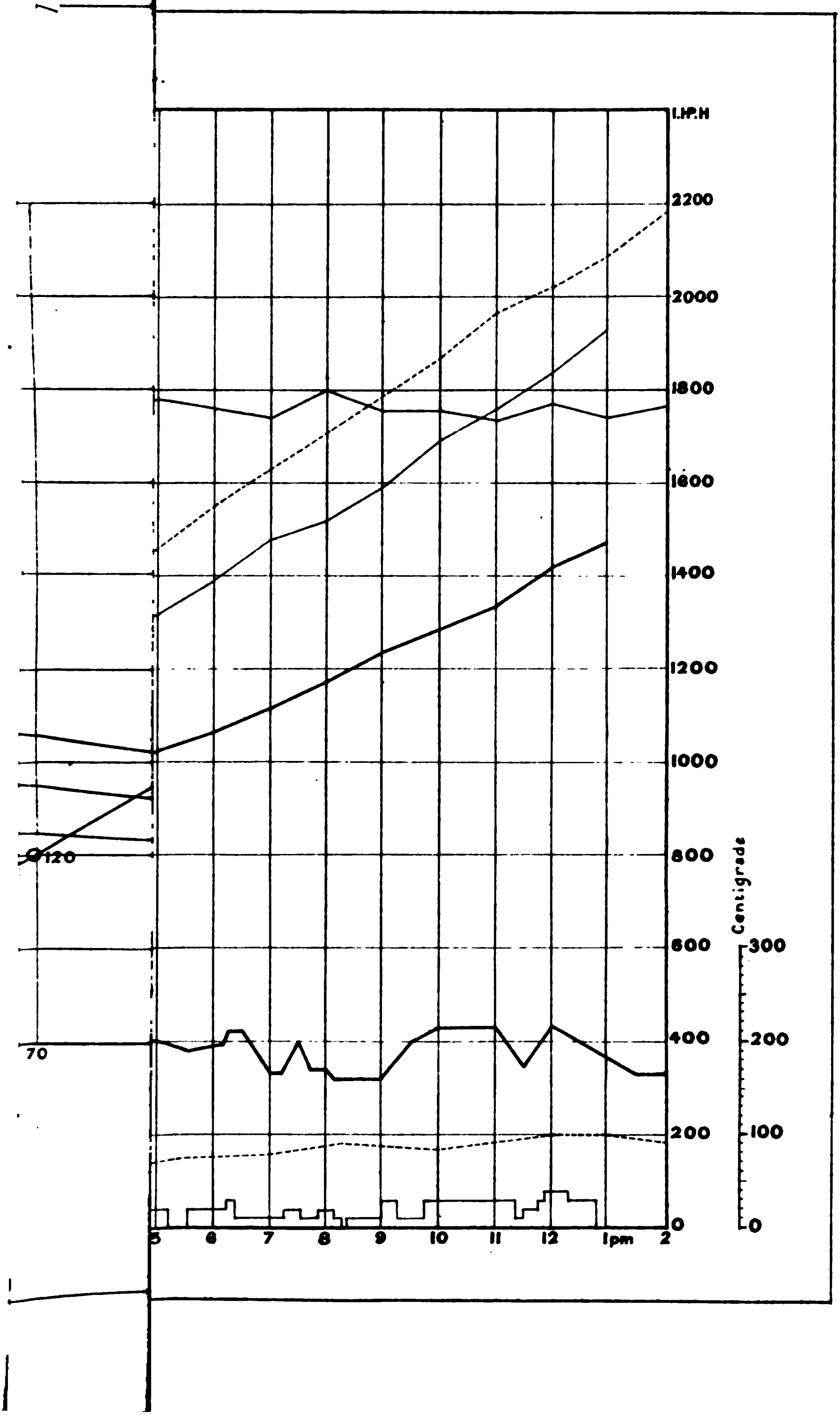
Associates:

John Henry Bale.	Christopher Charles Hart, jun.
Arthur Bentley.	Peter Charles Middleton.
William Clay.	Benjamin Young.

Students:

Archie S. Cubitt.	Owen David Lucas.
Albert Alexander Horn.	Percival Thomas Moor.

The meeting then adjourned.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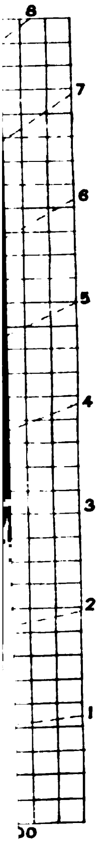

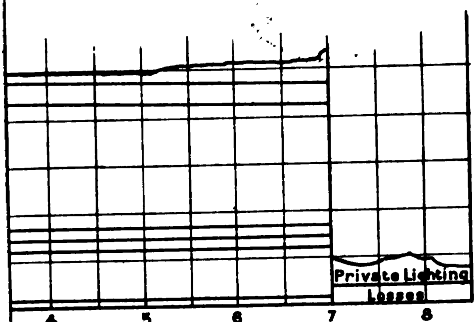

ABSTRACTS.

F. UPPENBORN—THE CENTRAL STATIONS OF MESSRS. SCHUCKERT & CO.: No. VI.—AIX-LA-CHAPELLE.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 11, *p.* 145.)

This article contains, among other detailed information about the station, a very interesting table containing the results of the tests carried out in March, 1893, with the plant, and of which an abstract is given below. The boilers are by Piedbœuf, of Aix-la-Chapelle, and are double, having a lower boiler for water and an upper one for the steam. The lower has two tubes like a Lancashire boiler, and the products of combustion are passed through 86 tubes in the upper compartment. The engines are triple-expansion and condensing, and the dynamos direct-coupled. The following table is for eight hours run in every case:—

I.—Steam Engine Trials.

	Machine 1.		Machine 2.	
	Normal Load.	Maximum Load.	Normal Load.	Maximum Load.
Mean speed	121·22	121·23	120·89	120·51
Mean output indicated in high-pressure cylinder in German H.P.	113·13	130·21	124·76	137·16
Mean output indicated in middle cylinder	102·39	116·59	102·95	119·52
Mean output indicated in low-pressure cylinder	174·33	206·40	172·36	201·70
Total indicated H.P.	389·85	453·20	400·07	458·38
Effective H.P....	346·0	407·41	355·0	416·80
Efficiency, per cent.	88·8	90·0	89·0	91·0
Electrical output	315·63	378·97	320·0	381·5
Efficiency of steam dynamo	81·7	83·6	82·5	83·0
Water consumption, kg.	22,388	25,593	24,758	28,348
Steam consumption (kg.) per effective H.P.-hour	7·35	7·38	7·60	7·54

II.—Boiler Tests.

	Nos. I. and II.		Nos. III. and IV.	
	Normal.	Maximum.	Normal.	Maximum.
Pressure (atmospheres)	10·85	11·0	10·93	10·7
Temperature of feed water, deg. C.	37·0	40·7	29·6	40·0
Coal consumption (coal of 7,856 calories), kg.	2,538	2,796	2,830	3,142
Steam per kg. net of coal	9·87	10·12	9·58	9·83
Temperature of products of combustion, degrees C.	148	140	150	140
Draught in mm.	5·5	5·8	6·0	5·5
Percentage of carbon dioxide ..	13	13	14	14·5

III.—Dynamo Tests.

	Dynamo I.		Dynamo II.	
	Normal.	Maximum.	Normal.	Maximum.
Mean current, amperes	667·21	927·6	655·88	951·1
Mean output, kilowatts	232·3	278·93	236·48	280·93
Mean electrical output per I.H.P. (German) in watts	596·4	615·46	590	615

The momentary speed variation for 25 per cent. change of load was 2½ per cent.

E. SCHULTZ—DIRECT-CURRENT POWER TRANSMISSION BY SERIES MACHINES.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 10, *p.* 137.)

This article contains an account of various work carried out in Germany under the above scheme by the Deutsche Elektricitäts-Werke at Aix-la-Chapelle. The author points out the cases in which the system is useful. The chief advantage of the series motor lies in the fact that the magnet coils have only a small part of the total potential difference between their terminals, and consequently much higher pressure can be used than with shunt-wound machines without similarly endangering the coil's insulation. Other advantages are the fact that the series machine has a greater efficiency with varying loads; and, finally, the great starting torque and the invariable position of the brushes.

F. UPPENBORN—THE CENTRAL STATIONS OF MESSRS. SIEMENS & HALSKE: No. III.—STOCKHOLM.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 9, *p.* 113.)

This station was begun in October, 1890, and the trial runs took place in July, 1892, the works being opened on the 1st of September of that year. The buildings have accommodation for the completed plant, but the engine room and accumulator house are only calculated for half the amount. The boilers, dynamos and engines, and accumulators are at present capable of supplying 10,000 80-watt lamps.

In the boiler house there are fitted two Babcock & Wilcox water tube boilers of heating surface of 1,870 square feet; and room is provided for five more of the same size. Every boiler has 96 tubes of 102 mm. diameter and about 16 feet long, divided into 12 groups of eight tubes. The boilers all feed into a common steam service pipe, having a branch to every steam engine. The boilers are fed by Worthington duplex pumps, which take the feed water from a reservoir below, which receives the condensation water. The fuel used is coke from the town gas-works. The steaming tests gave for every kilogramme of coke (deducting ash) 7·17 kilogrammes of steam, containing 2 per cent. of moisture.

The two steam engines now working are made by W. Lindberg's Co. in Stockholm, and are marine triple-expansion condensing engines. Their normal output is 250 H.P., and can be raised to 310 H.P. as a maximum. The cylinders are 371, 594, and 955 mm. in diameter respectively. At the trials these engines gave a consumption of 5·91 kilogrammes of steam per I.H.P. at the normal load, and 6·16 kilogrammes at the maximum output.

Each engine is directly coupled to a dynamo, the inside-pole machine of Siemens & Halske. These dynamos have six poles, and develop 340 volts and 670 amperes at 100 revolutions. At the trials the output was 330 volts × 686 amperes for 361·4 I.H.P. (German H.P. = 736 watts). They were run for 24 hours, and the rise of temperature of the armature was 35° C., and that of the field magnet coils 21°. The engine room has room for another similar dynamo of 500 H.P., and there is ground for enlargement. The batteries consist of 280 Hagen accumulator cells, arranged as two double batteries, and the three-wire capacity of the whole is 2,500 ampere-hours. The regulating arrangements are as usual, and the regulation is done by hand. The feeders are connected to the omnibus bars by automatic resistance regulators. The cables are armoured and lead-covered, laid direct in the ground in general, but in iron pipes where requiring protection. The main house fuses are so arranged that the house can be put on either side of the middle wire as required.

ANON.—STATISTICS OF EUROPEAN ELECTRICAL RAIL AND TRAM WAYS TO JANUARY, 1894.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 12, *p.* 170.)

The following table shows the tramways working, or building, in Europe up to January, 1894:—

Country.	Working.		Building.
	Length, Km.	Power in Kilowatts.	Length, Km.
Germany	102·0	2,934	66·1
England	71·4	2,993	21·4
Austria	33·4	1,115	—
Belgium	3·2	90	17·8
Spain	14·0	210	—
France	41·4	1,796	23·0
Italy	13·0	720	—
Roumania	—	—	5·5
Russia	3·0	90	7·0
Servia	—	—	10·0
Sweden and Norway... ...	—	—	6·5
Switzerland	23·6	706	10·6
Totals	305·0	10,654	173·9

The following figures relate to rail and tram ways working:—

Number of lines	43
Total length, kilometres...	305
Total power of stations	10,654 kilowatts.
Number of motor cars and locomotives ...	538
Number of trailing cars...	151
Total cars...	689

As to system, the following figures are given:—

Accumulator lines	2
Overhead conductors	31
Middle conductor	8
Underground conductor	2

The greatest plant capacity is that of the station of the City and South London Railway, with 1,200 kilowatts; next, the Liverpool Overhead Railway, with 900 kilowatts. The maximum gradients for ordinary lines are 10.5 per cent., and for toothed wheels up to 25 per cent.

GEROSA, FINZI, and MAI—HYSTERESIS IN MAGNETIC METALS.

(*Beiblätter, Vol.* 18, *No.* 3, *p.* 375)

Thin rods of hardened or soft wrought iron, steel, and nickel were subjected to increasing or decreasing magnetic fields while traversed by constant or alternating currents, and the intensity of magnetisation was measured by a magnetometer. The authors' results are, briefly, as follows:—

A direct current flowing in the rod from the north to the south pole always diminishes the intensity of magnetisation produced by the field. Interrupted currents (always flowing in the same sense) increase the effect of weak fields (10–18 C.G.S. units), and diminish that of stronger ones; in the case of nickel, the effect of all fields is diminished. On the other hand, constant or interrupted direct currents flowing from the south to the north pole increase the effect of the magnetic field. Alternating currents increase considerably the effects of weak fields, even when the rod had previously been traversed by constant or interrupted direct currents in either direction; but with greater strength of field an increase occurs only when the rod has not been previously traversed by a current from north to south pole; in the other case the alternating current diminishes the effect. The authors conclude from this that a current flowing in the wire makes a permanent alteration in it, which cannot be got rid of by Auerbach's method of demagnetisation.

The curves representing the intensity of magnetisation of rods traversed by currents as a function of the strength of field have less decided points of inflection than those taken with rods not carrying currents; and this effeet becomes more and more obvious when constant, interrupted, or alternating currents are used, and when the ratio of this current to the strength of field increases. This effect is more evident in the case of soft wrought iron than in hard iron, nickel, or steel; for example, with an alternating current of 3 amperes the hysteresis cycle of soft wrought iron completely disappeared.

In a second series of experiments the magnetised rod is surrounded by a little spiral of fine wire, through which an alternating current passes during the time that the magnetic field is in action. With a very small alternating current the hysteresis cycle completely disappears. It appears the more remarkable that, on the other hand, the intensity of magnetisation produced by weak fields is decreased by the alternating current flowing in the above manner. The curve representing under these circumstances the intensity of magnetisation of the iron up to saturation is not very divergent from a straight line.

F. KOHLRAUSCH—SOME FORMS OF ELECTRODES FOR THE DETERMINATION OF THE RESISTANCE OF ELECTROLYTES.

(*Wiedemann's Annalen, Vol.* 51, *No.* 2, *p.* 346)

The author describes three forms of electrodes which may serve to determine the electrical conductivity of liquids without removing them from their bottles or other containers. In preparing them he uses the fact that well-platinised electrodes

may be made smaller than is usual without fear of polarisation. In order to make the determinations of resistance independent of the depth to which the electrodes are lowered, or the area of the liquid, and to protect the electrodes from mechanical damage, the latter are placed in a small glass protecting tube, open at the bottom, and having a small hole at the top. The connections are carried by means of small glass tubes with platinum wires sealed into their ends, filled with mercury. The whole length of the system is 20–30 cm., its diameter about 20 mm., so as to be conveniently small for placing in bottles, and so on.

Of the three kinds described, the first serves for the determination of the conductivity of badly conducting liquids; the electrodes are flat, about 1 square centimetre in area, and are arranged parallel to one another about 1 mm. apart. They can be used for pure water, resistance about 100,000 ohms, and down to saline solutions of about 100 ohms.

The second kind is for very badly conducting liquids—for example, water—when a resistance of 100,000 ohms is not suitable for the measuring instruments. The electrodes are concentric cylinders made of platinum sheet about 3 cm. high. With this arrangement water is reduced to 10,000 ohms at most, and can be measured with simple instruments.

The third kind is for good conductors, and consists of two plates 2 cm. long, arranged below one another 5–10 cm. apart in the guard tube, or even outside and inside for very good conductors. This arrangement does not utilise all the portions of the electrodes equally, but practice shows no trouble from polarisation if the above dimensions are used.

H. DU BOIS—A RING ELECTRO-MAGNET FOR THE PRODUCTION OF INTENSE FIELDS.

(*Wiedemann's Annalen, Vol.* 51, *No.* 3, *p.* 537.)

Hitherto certain types of electro-magnet, especially the well-known form of Rhumkorff, chiefly of empirical design, have been used for the production of the intense fields required for many physical researches, but few of these produced fields greater than 28,000–30,000 C.G.S. units. The author described at the Frankfort Congress in 1891 the principle on which it would be possible to obtain still higher densities; and describes in the present article a ring electro-magnet made for him by Siemens & Halske, and which produces a strength of field of 38,000 C.G.S. units.

In the design of such an apparatus it is true that the rules followed for the magnet systems of dynamos are generally binding; but economy, safety, and accessibility for repairs are of much less importance. The chief object is to get as near as posible to saturation point of the magnetisation. Owing to the necessary air space between the poles, the magnetic resistance of the core cannot fall below a certain limit, so that the highest obtainable flow of induction can only be reached by increasing the ampere-turns, and this can be done all round the magnetic circuit. On theoretical grounds it is desirable, chiefly for the prevention

of leakage, to give the magnetic circuit the form of a radially split ring, and to crowd the induction by means of conical pole-pieces. The iron ring has a mean radius of 25 cm., and its section a mean radius of 5 cm. In the usual position the ring rests on its supports in such a manner as to bring the air gaps vertical which divide it into two halves. The lower slit has a means of rotating the halves of the ring in such a manner as to increase or decrease the distance between the pole-pieces above, and they are clamped in position by a screwed brass distance-piece; and with very small gaps plates of brass are used, placed between the pole-pieces. For the purpose of magneto-optical observations, the ring is bored horizontally where the pole-pieces are screwed on, the hole being usually filled with a loose piece of iron. The ampere-turns, when warm, are 108,000, or H = 136,000 C.G.S. units.

The pole-pieces provided are flat, plate-shaped, and conical. The best angle of cone, according to Von Stefan, Ewing, and Low, is 54° 44′. The author finds that it is sufficient if the angle lie between 57° and 63°. The plain cone is better than one with the sides concave or convex. With blunted conical pole-pieces of diameter a of the blunted point the following fields were attained:—

For $a = 5$ mm, H = 36,800 C.G.S.
$a = 3$ mm., H = 38,000 „

Such a large field can naturally only be attained by sacrificing its size, and all experiments must be conducted in a space only a few millimetres long. As the winding used nearly 5,000 watts, the current could only be on for a short time, and therefore ballistic methods of determining intensity cannot be used. For pole-pieces wider apart, therefore, the optical method was used. The holes alluded to above were covered with glass, and water was placed by means of a waterproof cloth between the poles. The rotation of the polarisation plane of sodium light so brought about was observed, and the magnetic difference of potential calculated by means of Verdet's constant. The thin glass covers have no appreciable effect.

When blunted-cone pole-pieces were used the intensity of field was made by Quincke's "rise of level" method. A U-tube with a "rising" arm with very thin sides was placed between the pole-pieces, the rising arm exactly between them, the reservoir arm being 20 cm. away. The vessel was filled with a quarter-saturated solution of manganese chloride. The greater the field the higher the level in the rising arm, if the whole arrangement be kept at such a level that the meniscus is always exactly in the middle of the field. The apparatus was calibrated by the optical method. The rise of the manganese chloride was up to 10 cm. According to Quincke, in a field of 38,000 C.G.S. units a solution of iron chloride would rise nearly 20 inches in the tube, water would fall 5 mm., and the resistance of a bismuth wire would be tripled.

— VOLLER—METHOD OF DEMONSTRATION AND INVESTIGATION OF ELECTRIC WAVES.

(*Beiblätter, Vol.* 18, *No.* 3, *p.* 382.)

The author begins by calling attention to the fact of the occurrence of very

different electric waves in one and the same wire, which makes the determination of the position of the nodes very difficult. In considering the method of Lecher for this determination, the author remarks that it has the disadvantage of requiring two wires, and an approximately parallel position. The Lecher method is also not very accurate, because it makes the determination of the nodes dependent on the maximum glow of the tubes; and it is also not suited for the investigation of waves in a metallically closed circuit. The author has extended the method to adapt it for closed metallic circuits, by only connecting one end of a tube with the wire carrying the wave. The tube must then begin to glow if the other end of the same has always zero-potential. By this amplification of the method one is enabled to investigate the wire carrying the waves by touching with the tube held in the hand the wire at any required point. The tubes used by the author are made of common glass and filled with rarefied air, or fluorescent glass filled with rarefied gases.

In one experiment the ends of the parallel wires were connected together, forming a circuit about 24 to 25 metres long; and this is found to contain four nodes. The author shows that with a definite position of the bridging wire, and of the length of wave in the primary circuit, by altering the length of the waves in the second circuit the waves become indefinite, and can only be restored by alteration of the primary system; and he points out that this has certain acoustical analogies. In order to vary the length of wave, the author employs different sizes of condenser plates. He also investigates the influence of the position of a wire in space on the position of the nodes of the waves, and concludes that the position of the wire has no influence on the result.

Spirally wound resonators give also nodes and waves like stretched wires, but the waves become very long.

In conclusion, the author investigates to what distance from the wire the surrounding dielectric has an effect on the results.

J. A. ROSENQVIST—RESEARCHES ON THE REFLECTION OF POLARISED LIGHT FROM MAGNETIC MIRRORS.

(*Beiblätter, Vol.* 18, *No.* 2, *p.* 232.)

These are researches on the phenomenon discovered by Kerr, that the plane of polarisation of a rectilinear polarised beam of light is rotated by reflection from a reflecting magnet pole or limb, and the light is altered from a rectilinear to elliptically polarised condition. The author used in the place of the surface of the magnet as a reflector a mirror of metal traversed by a current. If the direction of the current is at right angles to the plane of incidence, the same phenomenon occurs as when the reflection takes place from the side-surface of the magnet if the mirror is made of any magnetic metal; a diamagnetic mirror gave a negative result. The cause of the phenomenon is believed by the author to be the molecular currents arising in the mirror, and which, as shown by G. Wiedemann, make the surface of the mirror magnetic in such a manner that every particle has its northern end on the left when the current is from above to below. It follows,

then, that the electric current has only an indirect effect, by magnetising the mirror. It was found that the rotation of the polarisation was proportional to the current up to at least 8 amperes.

Mirrors of different thicknesses give different results, the rotation being greater for a thinner mirror. If the mirror was rotated on an axis at right angles to its plane, the current had a different position with regard to the plane of incidence. It was found that the rotation also depended on this being proportional to the sine of the angle between the direction of the current and the plane of incidence.

M. RESPIGHI—THE ELECTRIC TRAMWAYS OF GENOA.

(*La Lumière Électrique, Vol.* 51, *No.* 6, *p.* 276.)

These tramways were installed last year by Messrs. Siemens & Halske.

An overhead line is employed, and special precautions have been taken to minimise electrical risks by placing the line at a sufficient height from the ground.

Great care has been taken in very carefully insulating all parts of the system. The pressure employed is 500 volts. The line has been so erected, that no trouble has been experienced by the telephone companies. The transverse wires are 40 metres long, and are fixed to ornamental brackets. They are 5 mm. diameter, and are placed at a height of 7 metres above the road level. These wires are almost imperceptible, and the single service wire has the appearance of a telephone line.

Some of the slopes are as much as 7 or 8 per cent. Each car is designed to run at 12 kilometres per hour, with a load of 25 passengers, and must be capable of stopping when running either up or down hill. During a trial run 35 passengers were successfully carried.

The central station will be capable of developing 450 H.P. with three boilers, three engines, and three dynamos; two boilers, one engine, and one dynamo being kept as reserve.

The engines are by the firm of Tosi. They are of the compound tandem type. Admission to the high- and low-pressure cylinders is controlled by a Tosi regulator. The main dimensions of the engine are as follows:—Diameter of low-pressure cylinder, 47·5 cm.; diameter of high-pressure cylinder, 32·5 cm.; stroke, 35 cm.; revolutions, 260. Each engine has a normal output of 150 H.P., but can be worked up to 200 H.P. A condenser is employed capable of being used for two engines simultaneously. The boilers are of the Cornovaglia type, with two grates. The shell of each boiler is of mild steel; the external diameter 180 cm., that of the furnace 65 cm., and the total length 7·45 metres. Each boiler has a heating surface of 56 square metres, and the normal working pressure is 10·5 atmospheres. The feed water is supplied by two duplex steam pumps, one being kept as a reserve. The complete installation will consist of four engines and five boilers.

The dynamos, supplied by Messrs. Siemens & Halske, are belt-driven. They are compound-wound, and have internal poles. They have an output of 525 volts, 200 amperes, at 420 revolutions per minute.

The commutator has 260 parts. The resistance of the armature is 0·003 ohm,

and that of the field magnets 3·6 ohms. Their efficiency is 94 per cent. The bed-plates of the dynamos are insulated from earth by special insulators.

The distributing board consists of the following:—Three rheostats for the shunt circuits of the dynamos, three 200-ampere ammeters, one 550-volt voltmeter, three main switches, six 200-ampere cut-outs, four lightning protectors, one differential voltmeter for running the dynamos in parallel, and three automatic cut-outs.

The main cable is carried on posts, and has the following particulars:—Length of line, 1,250 metres; number of wires, 8; diameter of wires, 7·5 mm.; height above ground, 6·2 metres; distance apart of posts, 40 metres.

At the distributing point four of these wires are fixed to rails of the Phœnix type. The four others feed into the overhead line. The cars are worked in parallel.

M. M. MÈNE—PROTECTION OF TRAINS ON SINGLE LINES.

(*La Lumière Électrique*, *Vol.* 51, *No.* 6, *p.* 283.)

The object of this invention, due to M. Mène, is—

(1.) To prevent any collision between trains running in opposite directions; and to allow, as on a double line, free service for trains running in the same direction.

(2.) To indicate in a permanent manner at the stations the departure of a train, and its direction.

(3.) To allow of an express train service.

(4.) Not to compromise the safety of the system, in the event of the apparatus failing to work.

To accomplish the above, the line is provided at both ends of each section with a signal, to be locked under normal conditions, only to be freed when a train is passing, and to be locked directly afterwards.

The apparatus consists essentially of two distinct parts—the indicator and the lock, which are connected between each station by two line wires and an earth return. It is possible to work with one line wire only.

A. HESS—METHODS AND APPARATUS FOR MEASURING DIFFERENCE OF PHASE BETWEEN TWO SINUSOIDAL CURRENTS.

(*La Lumière Électrique*, *Vol.* 51, *No.* 10, *p.* 451, *Vol.* 51, *No.* 11, *p.* 509.)

It is useful to know the difference of phase between two currents in a great number of cases. The measure of the difference of phase between the electromotive force and current constitutes an indirect method of arriving at the inductance.

DIRECT METHODS.

The author first attempted to measure the difference of phase between the current passing into a condenser and the potential difference at the terminals by optically combining the two sine waves and producing Lissajou's figures. Two

electro-magnets with vibrating armatures were used for this purpose. It was, however, found difficult to work the shunt coil, although of high resistance. In the second instance, the author had recourse to direct measurement from the curves plotted along one axis. The instantaneous contact of M. Joubert was also used for this purpose By this method the author was able to detect variations in the difference of phase in a condenser with change of frequency.

M. Frölich suggested using a telephone the diaphragm of which would be fitted with a mirror. A beam of light reflected from the mirror might be thrown on to a rotating mirror, or impressed on a sheet of sensitised paper to which would be given a motion of translation.

It is necessary that the period of vibration of the diaphragm should be very small as compared to that of the current. Disturbing effects are due to mechanical inertia of the diaphragm, self-induction, and difference of phase due to hysteresis.

Mr. E. L. Nichols lately suggested sending a fine stream of mercury through a magnetic field, and photographing the transverse oscillations in the stream of mercury due to the passage of the alternating current through it.

M. A. Blondel's oscillograph consists of a galvanometer the coil of which has a very small moment of inertia. Very faithful reproductions of the curves have been obtained with this instrument.

Mr. W. Stuart Smith has worked on the principle of Ewing's magnetic curve-tracer. Two wires are stretched along the air gap of two electro-magnets excited by continuous currents. When alternating currents are sent through these wires they cause two mirrors to vibrate. Beams of light are thrown from these on to sensitised paper, and the curves obtained in the usual manner. From these curves the difference of phase can be measured.

Methods depending on Electrical Measurements.

Blakesley's well-known split dynamometer method. Three dynamometers are used, on which readings are taken simultaneously.

For reading the difference of phase between two differences of potential, M. Morelli suggests employing the above method, but using electrostatic voltmeters instead of dynamometers. Messrs. Blondlot and Curie's double needle electrometer would be used for reading the product of the two differences of potential.

An ordinary synchroniser, consisting of a small transformer with three windings, might be used for measuring the difference of phase between two alternating currents. If the two currents, I sin $w\,t$ and I sin $(w\,t + \phi)$, be in opposition, then the resultant magnetic field may be expressed by—

$$H = h \sin w\,t - h \sin (w\,t + \phi) = -h\,2 \sin \frac{\phi}{2} \cos \left(w\,t + \frac{\phi}{2}\right).$$

By connecting the third winding to a voltmeter a measure of the amplitude will be obtained and the value of ϕ deduced. If the two currents act in the same direction, the resultant action then becomes—

$$H = h \sin w\,t + h \sin (w\,t + \phi) = h\,2 \cos \frac{\phi}{2} \sin \left(w\,t + \frac{\phi}{2}\right).$$

M. Claude has suggested dispensing with the third winding and the voltmeter,

if the amplitude of the resultant magnetic field were obtained by measuring the temperature rise produced by Foucault currents in a mass of metal.

M. C. Claude's Phasemeter.—In this apparatus the resultant action of two magnetic fields produced by the currents, causes an armature of soft iron to vibrate. The amplitude of vibration must be observed by the deflection of a spot of light reflected from a small mirror fixed to the armature.

The cores of the electro-magnets are permanently magnetised, for if this were not the case the negative intensities of the field would act in the same direction as the positive intensities, and there would be as many attractions as half-periods of current, and the number of oscillations of the armature would be double the frequency of the current. By graduating the scale in degrees this instrument may be made direct-reading. The instrument is fitted with a reversing key for reversing the direction of the current in one of the electro-magnets, to make the amplitudes either proportional to cos $\frac{\phi}{2}$ or sin $\frac{\phi}{2}$, which increases the accuracy of the instrument for any difference of phase.

Tho two electro-magnets have exactly the same coefficients of self-induction, and high resistances are provided to place in series with the electro-magnets, in order that the ohmic resistance may be important as compared to the impedence.

M. Puluj's Experiments.—The apparatus consists of two electro-magnets identical in construction The core of each of these electro-magnets acts on a small piece of soft iron fixed to a spring, which vibrates when an alternating current passes through the electro magnet. These vibrators are placed at right angles to one another, and a small mirror is fixed to each. When the electro-magnets are excited, and a beam of light is thrown successively from one mirror to the other, and thence on to a screen, Lissajou's figures will be produced.

The position of the spot at any instant is given by the equations,

$$x = a \sin w t,$$
$$y = b \sin (w t + \phi),$$

of which a and b are the amplitudes of vibration, depending on the number of ampere-turns on the bobbins, and also on the distances of the armatures from the cores. When $\phi = 0$ a straight line will be seen on the screen, but when there exists some difference of phase between the two currents the path of the spot of light forms an ellipse. These ellipses have the characteristic of all being inscribed in one rectangle, of which the sides are equal to $2\,a$ and $2\,b$.

If $y = 0$ and $x = 0$ in the above equation, then one obtains—

$$\frac{y_0}{b} = \frac{x_0}{a} = \sin \phi.$$

The screen on to which the spot is projected has two scales, which cross one another at right angles, and which are divided in centimetres.

Instantaneous values of $2\,y_0$ and $2\,b$ must be measured. As a check, simultaneous values of $2\,x_0$ and $2\,a$ should also be taken. These measurements are, however, not easy to make, and are liable to some errors.

M. Climentich de Engelmeyer's Modification.—In order to facilitate the practical working of this apparatus, the influence of the amplitudes is eliminated, and $a = b$. To arrive at this result it is necessary to either alter the number of

ampere-turns on the bobbins, the position of the cores, or the distance of the bobbin from the vibrating armature. This last method is the best, for it does not alter the self-induction of the bobbin.

With equal amplitudes the equation for the resultant ellipse is—

$$x^2 + y^2 - 2xy \cos \phi = a^2 \sin^2 \phi;$$

and the lengths of the semi-axes are—

$$y_0 = a\sqrt{1 + \cos \phi},$$

$$x_0 = a\sqrt{1 - \cos \phi},$$

from which expressions the value ϕ could be obtained. It would, however, be an advantage to dispense with all measurements on the screen, which result could be obtained by placing the vibrators at an angle of ϕ to one another, or a supplementary angle to ϕ, instead of 90°.

The apparatus consists of two bobbins which act simultaneously on a single vibrator carrying a mirror. One bobbin may be moved nearer or farther from the vibrator, and the other bobbin may be moved over a graduated scale to make the necessary angle. By this method the angle of difference of phase is indicated on the divided scale, when the path of the spot of light forms a circle.

Acoustic Method.

M. Climentich de Engelmeyer's Apparatus.—It is first necessary to transform the current-waves into sound-waves. If interference takes place, a new set of stationary waves will be produced if the periods be equal, and the nodes and ventral segments will occupy definite positions determined by the difference in phase between the interference waves.

The apparatus consists of a tube of variable length closed at its two ends by two telephone diaphragms. If it be necessary to determine the difference of phase between two currents of equal frequency and of the same amplitude—viz., $I \sin wt$ and $I \sin (wt \pm \phi)$—on sending currents through the electro-magnets sound waves will be set up, $A \sin wt$ and $A \sin (wt \pm \phi)$, which meet in the tube, and by virtue of the interference set up produce a resultant stationary wave of which the amplitudes of vibration at different points in the tube are defined by the expression,

$$M = 2 A \sin \pi \frac{x - (y \pm \phi)}{\lambda},$$

where x and y are the respective distances from the diaphragms measured in wave-lengths, and λ the wave-length corresponding to the frequency of the current employed. The node of vibration at any point may be found from the relation,

$$\frac{x - (y \pm \phi)}{\lambda} = n.$$

If the diaphragms be actuated by the same current $\phi = 0$. The position of the first node is then defined by $x - y = 0$. The presence and position of this node may be verified by means of an exploring tube connected to the ear. The two currents are then made to actuate the diaphragms, and the position of the node will then be defined by $x - y \pm \phi = 0$. It is preferable to lengthen the tube and bring the node to its original position. And the amount by which it must be lengthened is $y - x = \pm \phi$. This expresses exactly in wave-lengths the difference of phase

between the two currents, and the sign of the variation of length indicates the sign of the difference of phase.

The Acoustic Synchroniser of the General Electric Company.—This consists of a metallic cylinder with a circular aperture at the side, and is closed in at each end by two diaphragms, acted upon by two electro-magnets, excited by the two alternators to be coupled in parallel.

When the machines are not in phase periodic sounds are produced in the synchroniser. As the difference of phase is reduced, so the period of the sound becomes greater; and it is only when the machines are perfectly in phase that no sound will be heard at all, and at this time a node will exist at the aperture of the cylinder.

Methods based on the Properties of Rotating Magnetic Fields.

The Author's Method.—With any given alternating current a rotating magnetic field can be produced by causing the current to pass through two parallel circuits each containing a coil. If the two circuits have a different inductance, and if the axes of the coils make a given angle with one another, a rotating magnetic field of constant intensity will be produced of which the diagram is a circle.

When the two currents are sent through the two coils fixed at right angles, it is necessary that the two currents should be in quadrature, in order to produce a rotating field with a circular diagram.

The two systems must also present the same inductance, in order that the difference in phase between the two currents should not be affected The fields are regulated in order that they should have the same amplitude, and the circuits so arranged that the fields rotate in opposite directions. By passing the same current through the two pairs of circuits in series, the origin of the angle to be measured may be defined experimentally. The same result may be arrived at by putting the coils in parallel, and by suitable adjustment. The amplitude of the fields may be regulated by altering—

(1) The resistance of the circuits;
(2) The number of active turns in the coils;
(3) The distance of the coils from the centre of intersection of the fields.

In practice, to produce a quarter phase difference between two alternating currents, necessitates the use of condensers. Their use can be dispensed with if it be possible to utilise a difference of phase less than 90°. The diagram of the resultant field would then be an ellipse, which might be transformed into a circle by varying the angle between the two coils. The ellipse produced by two magnetic fields with a difference of phase ϕ has the following coefficients:—

$$A = \frac{1}{H^2 \sin^2 \phi},$$

$$B = \frac{1}{H'^2 \sin^2 \phi},$$

$$C = \frac{-2 \cos \phi}{H\,H' \sin^2 \phi},$$

which can be transformed into a circle by satisfying certain conditions.

M. Korda's Method.—A coil placed in a rotating magnetic field, and rotating

in synchronism with the field, cannot become the seat of any current so long as the diagram of the fiel l remains a circle and the axis of rotation is perpendicular to the plane of the field. But if either of these conditions ceases to be fulfilled currents are set up in the coil with twice as many periods as that of the field. It is then necessary to transform the diagram into a circle by altering the angle of one of the coils. No current should be indicated on a voltmeter or telephone connected to the rotating coil. The angle through which the coil must be turned is the supplementary angle to ϕ.

Apparatus of the Allgemeine Electricitäts Gesellschaft.—This consists of two rectangular bobbins producing an elliptic field when excited by the two alternating currents. An iron needle controlled by a spring is placed in the field. The position of the axes of the ellipse will vary with the difference of phase: the needle will tend to follow the major axis of the ellipse, and a deflection is produced being a measure of the difference of phase.

C. JACQUIN—TRANSMISSION OF MOTIVE POWER BY POLYPHASE CURRENTS TO THE JURA-SIMPLON WORKSHOPS.

(*La Lumière Électrique*, *Vol.* 52, *No.* 14, *p.* 10, *Vol.* 52, *No.* 15, *p.* 73)

A waterfall 50 metres high, near Bougean, in the Jura, has been utilised for purposes of transmission of power. All the works of the Jura-Simplon Railway Company are at Bienne, at a distance of 2 kilometres from the fall. The firm of Lahmeyer, of Frankfort, supplied the p'ant, using the same system as at Bockenheim. This consists of the transmission of polyphase currents from the generating station; at a secondary station a portion of the current is directly utilised for working high-tension polyphase motors. The remaining portion is transformed into a continuous current, which is distributed in the neighbourhood of the station on the low-tension system at 100 volts. The exciters are also used for supplying continuous currents outside the station.

The triphase alternators work at 80 volts, which pressure is transformed up to 1,800 volts. The primary generating station is installed in a mill situated on the banks of the Suze, near the bridge at Bougean. The water is led to Bougean by a conduit 760 metres long and 1 square metre in section. This conduit has a head of 50 metres above the level of the river, and can deliver as a minimum 1·5 cubic metres per second of water at all times of the year, which corresponds to 850 H.P.

The set of machines at present installed in the generating station have an over-all measurement of 15 × 10 × 7 metres; but the building is large enough to take two such sets. One three-phase alternator is fixed on each side of the turbine, and from the turbine shaft are driven by belt two continuous-current machines. A telephone room is placed in one corner of the station. Water is admitted to the turbine through a cast-iron pipe 280 metres long. Water is discharged from the turbine through a pipe 50 metres long. From the turbine shaft is also driven a governor which acts directly on the admission valve. It was specified that between full and 0 load the speed of the turbine should not vary by more than 5 per cent.

The firm of Rieter & Co., of Winterthur, supplied the governors, which, after careful tests, were found to regulate within 3 per cent. between full and half loads The speed of the turbine is 300 revolutions per minute, and the efficiency was found to be over 75 per cent.

The low voltage of the alternators renders their construction very mechanical and safe. The field magnets revolve, and consist of two star-shaped castings keyed to the shaft, and form 16 poles. The magnetic field is produced by one central coil. The armature is made up of laminated iron fixed to an outside ring of cast iron. The armature is traversed by 48 copper rods, 10 mm. diameter, insulated by a sleeve of asbestos. The three armature circuits are coupled to form a star connection. Each circuit consists of 16 coils, each made up of three of the copper bars. The alternators are capable of giving 800 amperes at 80 volts. The exciters are four-pole machines capable of giving 8·8 kilowatts at 110 volts at a speed of 1,100 revolutions.

Each alternator requires an exciting current of 8·5 amperes at 110 volts, being 1·5 per cent. of the full-load output of the machine. Bare copper strips 250 mm. square section, supported on insulators, are run from the alternators to the switch-board. The latter is 3·5 metres wide and 2·2 metres high. It is raised about 1 metre from the floor of the station, and is reached by means of a small staircase. Although both alternating and continuous currents are employed, the switch-board is extremely simple. Provisions are made for running the dynamos in parallel.

The overhead lines each consist of three naked copper wires. The six wires are run together on posts for 2 kilometres as far as Bienne; at this point a branch circuit is taken to the shops of the Jura-Simplon Railway Company.

At the sub-station at Bienne the triphase current at 1,800 volts will be transformed into a 110-volt continuous current by means of special dynamotors.

The railway station takes about 20 kilowatts, and 20 kilowatts are also required for the purpose of charging accumulators in certain buildings.

The Lahmeyer motors employed on these circuits are of the non-synchronous type, with rotating field magnets and fixed armature. The latter is made up of laminated iron threaded through by a number of copper bars connected in parallel at each end. The field magnets consist of a drum of laminated iron carrying three coils of insulated copper wire, coupled to form a star connection, the outer end being fixed to three collecting rings fixed on the spindle. The current, before entering the motor, passes through the necessary instruments on a switch-board, and through a water resistance. The starting and stopping of the motor is effected by varying this resistance. The machine is started without the slightest difficulty, provided it is not over-loaded.

G. RICHARD—ALUMINIUM AND ITS ELECRO-METALLURGY.

(*La Lumière Électrique, Vol.* 52, *No.* 14, *p.* 16.)

Experiments are still being made to find a suitable solder for aluminium.

MM. Nicholas and Legenbach lately proposed using chloride of silver. This, however, had been previously tried on several occasions, notably by M. E. Thomas.

He described chloride and bromide of silver as forming good solders for aluminium, giving homogeneous and strong joints. This process would be of great commercial value if the salts were cheaper, and if the action took place at a temperature under 500° or 600°. A great objection to the process is that the joints blacken on exposure to light. Apart from these disadvantages, the process is preferable to all others with regard to strength.

M. Daggen has recently given much attention to alloys of aluminium with other metals. The simplest alloy, aluminium-bronze, is prepared either in an electric furnace by the Cowles process, or by the addition of aluminium to a bath of molten copper. The alloy obtained by the former process has approximately the following composition: Aluminium, 20 per cent.; silicon, 4 per cent. iron, 4 per cent.; copper, 72 per cent. A much purer alloy is obtained by the latter process. Up to 9 per cent. an alloy with fibrous texture is obtained; with 10 and 11 per cent. it becomes crystalline.

Attention has also been given, by the United States Naval Department, and the Aluminium Company of Neuhausen, to alloys containing copper and zinc. They had approximately the following composition:—

Cu.	Al.	Si.	Zn.
63	3·3	0·33	33·3

The addition of zinc produces a fine-grained brittle alloy with a lower melting point than that of the constituent metals. An alloy made with 3 per cent. of German silver is very elastic and durable.

In the case of silver, an addition of anything up to 6 per cent. will increase the elasticity and durability; but anything more than 6 per cent. causes brittleness. Alloys may be made with as much as 30 per cent. of silver, to be used for the manufacture of objects not requiring the above properties.

Aluminium containing more than 1 or 2 per cent. of iron is brittle; with 8 per cent. it crystallises in needles.

Iron castings containing 15 to 16 per cent. of aluminium are very hard and can scarcely be filed. Such castings present a fine crystalline fracture. Steel containing 1 per cent. of manganese and 7 per cent. of aluminium nearly cuts glass. Aluminium is frequently used in iron and steel foundries in the United States and in England; the proportions used are very small.

The influence of the metal, according to M. Daggar, is as follows:—

1. The aluminium transforms the combined carbon into free graphite at the moment of solidification. When added to iron castings, 0·25 per cent. will cause a change in colour, and 0·75 per cent. produces a grey casting. Up to 4 per cent. the tendency is to produce soft grey castings.

2. A reduction takes place in the oxides of iron and silicon.

3. A reduction of the gases in the molten metal also takes place.

M. Grabau has recently published the following process for the manufacture of pure fluoride of aluminium without the use of either iron or silicon:—

Powdered or calcined kaolin, as free of iron as possible, is treated with hydrofluoric acid or hydrofluosilic acid. The temperature of the reaction should not exceed 95°. After a few minutes the reaction is completed, and there should remain a neutral solution of fluoride of aluminium without any free silicic acid.

After filtration there will remain a precipitate of silicic acid and kaolin, which must be washed with hot water and re-treated as described above. By this process about 95 per cent. of the hydrofluoric acid employed is found under the form of fluoride of aluminium. If 12 per cent of hydrofluoric acid were employed, the solution would contain about 15 to 16 per cent. of fluoride of aluminium ($Al_2 Fl_6$).

The electrolytic system invented by Mr. J. B. Hall for the extraction of aluminium, consists of an anode and cathode consisting of a mixture of carbon and aluminium. The bath is formed of a mixture of fused chloride of aluminium, calcium, and lithium. An electric current decomposes the anode, and the aluminium taken from it is deposited on to the cathode in the form of a precipitate. At the same time the oxygen which is liberated combines with the carbon of the anode. It is necessary to replace the anode from time to time when used up. To obtain aluminium-bronze it is only necessary to place a sheet of copper in the bath.

A good deal of attention has been paid of late in the United States and in Germany to the electro-metallurgy of iron. Mr. Taussig's process consists in placing the metallic oxides to be reduced in a furnace, after having well pulverised them, and then submitting them to the action of an electric current passing between two large electrodes. The intensity of the current must be sufficient to fuse the oxides. According to the inventor, intensities of 20,000 and 30,000 amperes are not too high.

If 30,000 amperes at 50 volts be employed, which is equivalent to 2,000 H.P.—a little lower than the power employed at Neuhausen—the effective space taken up by the molten metal would be 12 metres by 150 square centimetres at least. This would give a volume of 180,000 cubic centimetres, or about 1,400 kilogrammes of metal. An installation of this sort would be capable of melting about 1,400 kilogrammes in one operation occupying about 15 minutes. This process is considerably cheaper than the ordinary crucible process for the manufacture of steel, for less than one-half the quantity of combustible is consumed.

R. JANET—AN ELECTRO-CHEMICAL METHOD OF OBSERVING ALTERNATING CURRENTS.

(*Comptes Rendus*, *Vol.* 118, *No.* 16, *p.* 862.)

There are two factors in connection with alternating currents which are not always easy to measure—viz., frequency and difference of phase. It may be necessary to measure frequency accurately when one is placed far away from the source of supply. With reference to difference of phase, of which an accurate measurement is so important in many cases, all methods in use at the present time have the disadvantage of being both indirect and complicated, and also necessitate the use of instruments possessing self-induction, which tends to inaccuracy.

The author has devised a graphical method offering great facilities for making measurements. Over a recording metallic cylinder is placed a sheet of paper which has been soaked in a solution of ferro-cyanide of potassium and nitrate of ammonia. An iron or steel style is made to press against this paper. The

cylinder and the style are then connected respectively to the two points across which it is necessary to study the periodic E.M.F. As the circuit has no self-induction the current will be in phase with the E.M.F. If under these conditions the cylinder be rotated, periodic blue lines will be produced corresponding to the maximum values of the E.M.F.'s. By this method frequency can be very readily measured.

For measuring the difference of phase between two electro-motive forces of the same frequency, it is only necessary to record the two impressions side by side, and to measure the distance between the two maximum values.

By this method it would be easy to measure the difference of phase between the primary and secondary currents and electro-motive forces of a transformer.

The author has found this method capable of being applied to many cases.

Experiments were made on currents obtained from Zipernowsky alternators at 110 volts.

1. Three points—A, B, C—on the circuit were taken, and separated by non-inductive resistances consisting of incandescent lamps. The point B was connected with the cylinder, and A and C with two styles. Under these conditions two discontinous lines were obtained; the maxima of one separating into two equal parts the intervals formed by the maxima of the other.

2. An inductive resistance was inserted in place of one of the above non-inductive resistances. The difference of phase was immediately changed. The maxima of the discontinuous line corresponding to the inductive resistance separated into two parts, the intervals of the maxima corresponding to the lamp resistance.

J. H. VAIL—ON THE IMPORTANCE OF COMPLETE METALLIC CIRCUITS FOR ELECTRIC TRAMWAYS.

(*La Lumière Électrique*, *Vol.* 52, *No.* 17, *p.* 178.)

When electric traction was practically introduced, two systems of conductors were in use. One was the double overhead line, and the other the single line with earth return. The latter is the system which has survived, on account of its simplicity.

The resistance of the earth return is made as low as possible by sinking earth plates at certain distances apart, and connected to the rails; or by running an earth wire along the track, connected to the rails at certain distances. This auxiliary return is necessary, for without it serious electrolytic effects take place on iron and lead pipes, on account of their being better conductors than the earth. This electrolytic effect is considerably increased at places where gas pipes have leaked. On a line where the rails are connected to the water pipes, experiments showed that the pipes take 28 per cent. of the current. This has in cases reached as much as 40 per cent. of the total current.

Tests have shown that the electrolytic action of a 5-ampere current produces in time serious effects on iron pipes. The rate at which the action takes place depends on the nature of the soil, and its dampness, and also on the intensity of the current

One of the chief faults of the existing systems is the insufficient number of joints between the rails. The fish-plates and bolts are not sufficiently good joints, their resistance being very great as compared to that of the rails. It is, however, difficult to tell when a joint is defective. The two main indications are the shaking of the train when passing over it, and also, in winter, the melting of the snow at that place, due to the production of heat.

The section of the rails themselves is sufficient to carry 800 to 900 amperes without heating, when the two rails are in parallel. It is, therefore, evident that excellent joints are required.

The author could mention cases where the auxiliary copper return has been entirely dispensed with.

In order to minimise the drop on the return it would be necessary to use feeders connected to the rails at points not too far apart; and the author recommends the use of insulated feeders. The increased expense, in his opinion, is entirely compensated for by the diminished deterioration of the joints, and by the increased efficiency of the line.

This system would have all the advantages of the double overhead line, with none of the disadvantages of the present system.

ANON.—PURIFICATION BY ELECTROLYSIS OF SUGAR SOLUTIONS.

(*La Lumière Électrique, Vol.* 52, *No.* 16, *p.* 124.)

Dr. Bersch has recently experimented on the electrolytic process of Schollmeyer, Behne, and Dammeyer for the purification of sugar solutions. The juice obtained from the diffusers at a temperature of 40° or 45° is heated to 65°, and transferred to the electrolyser, consisting of an iron tank divided into two parts. Each of these compartments, of which the capacity is about 1,500 litres, with a height of 0·50 metre, contains seven sheet zinc electrodes, making a surface of 6 square metres. The two compartments are alternately filled with solution, which is treated for about 10 minutes with a current of 50 to 60 amperes.

On the negative pole is formed a gelatinous deposit of a greenish grey colour, and the inventors consider that the zinc in combining with the alkalies facilitates crystallisation. The thicker this deposit the greater the resistance offered to the current; it is therefore necessary every week to reverse the current for about five minutes: the gases generated will detach the deposit. The process of electrolysis produces a gelatinous precipitate which renders filtration difficult. To obviate this a small quantity of lime is added to the solution.

With the old process of evaporation trouble was experienced due to the formation of froth, especially with beetroots of inferior quality; but with the electrolytic process no froth is formed, and in the heating process no harm is done to the sugar. After heating, the solutions treated electrolytically yield on the average 69·5 per cent., giving 98 on the polarimeter, and contain 0·48 per cent. of ash.

According to Dr. Bersch, the prime cost is very low, and the consumption of zinc is negligible. At Hoym, where the experiments were carried out, the profits made in one week paid for the cost of installation. The current required was 50 to 60

amperes, with 6 volts. It is therefore advisable to have a 1-H.P. dynamo, which allows of margin for the process of clearing the sugar electrically.

ANON.—FELTEN & GUILLEAUME CABLES (1893).

(*La Lumière Électrique*, *Vol.* 52, *No.* 16, *p.* 125.)

These cables consist of a helicoidal insulating core having grooves into which strands of wire are laid, and the whole covered with insulating material, and finally lead-covered. Cables for the three- or five wire system are made in this way.

ANON.—THE ACCUMULATOR PLATES OF THE SOCIÉTÉ DE CONSTRUCTION MÉCANIQUE ET ÉLECTRIQUE DU NORD.

(*La Lumière Électrique*, *Vol.* 52, *No.* 16, *p.* 125.)

The present plates consist of a lead grid alloyed with antimony, as a support for the active material. A new plate has, however, been designed to entirely prevent buckling. These plates are made up of 12 lead combs, the teeth of which fit into one another, leaving small spaces to allow of free circulation of liquid. The top parts of these combs are soldered together, but their lower ends are free, being only held in position by a lead wire connected to the two outside strips. The process of forming may be carried out very rapidly, on account of the large surface exposed.

ANON.—FUSIBLE WIRES FOR PROTECTING TELEGRAPHIC APPARATUS.

(*La Lumière Électrique*, *Vol.* 52, *No.* 15, *p.* 80.)

M. Strecker has suggested the use of wires 0·03 mm. in diameter, made of an alloy known under the name of "Constantan," which would melt at 0·3 ampere. It might in cases be necessary to use wire 0·2 mm. diameter, which would be too fine to handle.

To overcome this difficulty M. Feussner has suggested the use of a fine wire fixed at one end to a hook of easily fused metal, and kept tight by a spring. The hook will be fused when the wire reaches a certain temperature.

CLASSIFIED LIST OF ARTICLES

RELATING TO

ELECTRICITY AND MAGNETISM

Appearing in some of the principal Technical Journals during the Month of APRIL, 1894.

S. denotes a series of articles. I. denotes fully illustrated.

LIGHTING AND POWER.

C. Jacquin—Transmission of Motive Power by Polyphase Currents to the Jura-Simplon Workshops.—*Lum. El.*, vol. 52, No. 14, p. 10, No. 15, p. 73 (I.).

H. de Graffigny—Domestic Electric Lighting.—*Ibid.*, p. 30 (I.).

G. Claude—Questions relating to the Introduction of Central Stations.—*Lum. El.*, vol. 52, No. 15, p. 51.

G. Richard—The Mechanical Applications of Electricity.—*Ibid.*, No. 15, p. 59, No. 17, p. 154 (S. I.).

G. Richard—Arc Lamps.—*Lum. El.*, vol. 52, No. 16, p. 106 (S. I.).

H. de Graffigny—A Study of some New Gas and Oil Engines.—*Lum. El.*, vol. 52, No. 16, p. 120, No. 17, p. 170 (S. I.).

Anon.—The Laval Turbo-Motor.—*Lum. El.*, vol. 52, No. 17, p. 179 (I.).

H. Zerener—On the Deflection of the Electric Arc by Magnetism and Electric Welding.—*Beibl.*, vol. 18, No. 4, p. 470.

P. Janet—The Latest Applications of Electricity to the Industries.—*Ibid.*, p. 485.

R. Dahlander—The Transmission of Power, Hellsjön-Grängesberg, in Sweden.—*E. T. Z.*, 1894, No. 14, p. 201 (I.).

L. Baumgardt—A System of Power Distribution for Workshops.—*E. T. Z.*, 1894, No. 16, p. 221 (I.).

— Passavant—Contributions from the Experience of the Berlin Electricity Works.—*Ibid.*, p. 230.

ELECTRIC TRACTION.

J. H. Vail—On the Importance of Complete Metallic Circuits for Electric Tramways.—*Lum. El.*, vol. 52, No. 17, p. 178.

DYNAMO AND MOTOR DESIGN.

E. C. RIMINGTON—On the Behaviour of an Air-Core Transformer when the Frequency is below a certain Critical Value.—*Phil. Mag.*, vol. 37, No. 227, p. 394 (I.).

T. MARCHER—New Dynamo and Motor of the Firm of Pöschmann & Co., of Dresden.—*E. T. Z.*, 1894, No. 14, p. 193 (I.).

TELEGRAPHY AND TELEPHONY.

— CAILHO—Description of a Method of Simultaneous Telegraphy and Telephony on the same Wires.—*Ann. Tel.*, vol. 21, January-February, 1894, p. 5 (I.).

H. PELLETIER—The Marseilles-Tunis Cable.—*Ibid.*, p. 35.

A. REYNIER—The Laying of the New Caledonia-Australia Cable.—*Bull. Soc. Int.*, vol. 11, No. 107, p. 152.

ANON.—Telephonic Tariffs.—*Jour. Tel.*, vol. 18, No. 4, p. 89 (S.).

P. G. H. LINCKENS—The Influence of Telephony on Telegraphic Progress.—*Ibid.*, p. 108.

ANON.—Organisation of the Service of Accident Alarms on the Telegraphic System of the German Empire.—*Ibid.*, p. 110.

MERCADIER and ANIZAN—Microphonic Adapter for different Distances.—*Lum. El.*, vol. 52, No. 14, p. 27 (I.).

ANON.—Fusible Wires for the Protection of Telegraph Apparatus.—*Lum. El.* vol. 52, No. 15, p. 80.

ANON.—The Bonnard & Piat Telephone.—*Lum. El.*, vol. 52, No. 16, p. 131 (I.).

A. HESS—Telephonic Meters.—*Ibid.*, No. 17, p. 163 (I.).

ANON.—Supports for Telegraph Poles.—*Ibid.*, No. 17, p. 179 (I.).

— BUELS—Observations on Bronze Wire in Telegraphic Service.—*E. T. Z.*, 1894, No. 14, p. 189.

L. KOHLFÜRST—Reiner's Single Call for Telephone Installations.—*Ibid.*, p. 191 (I.).

INSTRUMENTS AND MEASUREMENTS.

— POMEY—Note on the Escapement of a Wheatstone Transmitter.—*Ann. Tel.*, vol. 21, January-February, 1894, p. 32.

H. ABRAHAM—Note on the Measurement of Coefficients of Induction.—*Jour. de Phys.*, April, 1894, p. 145 (I.).

ANON.—The Bell Switch.—*Lum. El.*, vol. 52, No. 14, p. 33 (I.).

ANON.—The Butre Thermostatic Regulator.—*Ibid.*, p. 34 (I.).

ANON.—The Blakey Automatic Signal.—*Ibid.*, p. 35 (I.).

ANON.—The Smith & Granville Relay.—*Ibid.*, p. 36 (I.).

ANON.—The Thomson Lightning Arrester.—*Ibid.*, p. 37 (I.).

ANON.—Apparatus for Winding Automatically by Electricity Clockwork and all Mechanism where a Weight is the Source of Movement.—*Ibid.*, p. 37 (I.).

ANON.—The Fegs & Lorwa Meter.—*Lum. El.*, vol. 52, No. 16, p. 129 (I.).

C. HENRY—A New Method of Photometry of Lights of different Colours by O. N. Rood.—*Lum. El.*, vol. 52, No. 17, p. 151.

L. DOPERÉ—A New Leyden Jar.—*Beibl.*, vol. 18, No. 4, p. 463.

C. CHRISTONI—Single Suspension Line Magnetometer.—*Ibid.*, p. 465.

G. S. MOLER—Rapid Alterations of Potential, investigated by means of a Registering Voltmeter.—*Beibl.*, vol. 18, No. 4., p. 479.

ANON.—Pocket Galvanometer of Siemens & Halske.—*E. T. Z.*, 1894, No. 14, p. 192 (I.).

O. FRÖLICH—Measurement of Insulation Resistance by means of the Detector, in Direct-Current Stations when in Working.—*Ibid.*, p. 193 (I.).

ANON.—Mirror Galvanometer with Liquid Damping of Siemens & Halske.—*E. T. Z.*, 1894, No. 15, p. 210 (I.).

A. KŒPSEL—Apparatus for the Determination of the Magnetic Properties of Iron in Absolute Measurement.—*Ibid.*, p. 214 (I.).

H. MÜLLER—Arrangement of Voltmeters for Putting Alternators in Parallel.—*E. T. Z.*, 1894, No. 16, p. 223 (I.).

MAGNETISM.

P. CURIE—Magnetic Properties of Iron at different Temperatures.—*C. R.*, vol. 118, No. 15, p. 796, No. 16, p. 859 (I.).

A. BATTELLI—Measurements for the Construction of a Magnetic Map of Switzerland.—*Beibl.*, vol. 18, No. 4, p. 482.

E. ODDONE—On the Variations of Intensity of the Magnetism of Rocks.—*Ibid.*, p. 483.

W. KUNZ—On the Dependence of Magnetic Hysteresis on Temperature.—*E. T. Z.*, 1894, No. 14, p. 194 (I.).

A. FÖPPL—On the Magnetisation of Hollow Iron Cores.—*Ibid.*, No. 15, p. 209.

H. ZIELINSKI—On the Magnetic Property of Discharges of Static Electricity, and its Practical Application.—*Ibid.*, No. 17, p. 233 (I.).

STATIC AND ATMOSPHERIC ELECTRICITY.

J. J. THOMSON—On the Electricity of Drops.—*Phil. Mag.*, vol. 37, No. 227, p. 341 (I.).

V. DUCLA—Experiments on the Weight of Electrified Bodies.—*C. R.*, vol. 118, No. 14, p. 749.

E. SARASIN and K. BIRKELAND—On the Reflexion of Electric Waves at the End of a Conductor terminating in a Plate.—*C. R.*, vol. 118, No. 15, p. 793 (I.).

V. DUCLA—On the Increase in Weight of a Charged Leyden Jar.—*Ibid.*, p. 832.

R. SWYNGEDAUW—The Distribution of the Discharge of a Condenser between Two Conductors, one having an Interruption.—*C. R.*, vol. 118, No. 17, p. 920.

D. Mazotto—On the System of Nodes of Electric Waves produced by Lecher's Method.—*Beibl.*, vol. 18, No. 4, p. 475.

E. Salvioni—Researches on Stationary Electric Waves.—*Ibid.*, p. 477.

E. Goldstein—On the so-called Striation of the Kathode Light of Induced Discharges.—*W. A.*, vol. 51, No. 4, p. 622 (I.).

ACCUMULATORS.

Anon.—The Hough Cell.—*Lum. El.*, vol. 52, No. 14, p. 32.

Anon.—The Petschel Cell.—*Ibid.*, p. 33 (I.).

Anon.—The Niblett Cell.—*Ibid.*, p. 33.

Anon.—The Accumulator Plates of the Société de Construction Mécanique et Electrique du Nord.—*Lum. El.*, vol. 52, No. 16, p. 125 (I.).

ELECTRO-CHEMISTRY AND METALLURGY.

P. Janet—On an Electro-chemical Method of Observing Alternate Currents.—*C. R.*, vol. 118, No. 16, p. 862.

G. Richard—Aluminium and its Electro-Metallurgy.—*Lum. El.*, vol. 52, No. 14, p. 16 (I.).

Anon.—Muirhead & Dearlove's Graduated Cells.—*Ibid.*, p. 32.

Anon.—Electrolytic Preparation of Bichromate of Cerium.—*Ibid.*, p. 32.

Anon.—Electrolytic Softening and Polishing.—*Ibid.*, p. 34.

Anon.—The Mestern Thermo-electric Cell.—*Ibid.*, p. 35 (I.).

Anon.—The Barnett Platinised Electrodes.—*Ibid.*, p. 36.

Anon.—Purification by Electrolysis of Sugar Solutions.—*Lum. El.*, vol. 52, No. 16, p. 124.

Anon.—The Kellner Electrolyser.—*Ibid.*, p. 130 (I.).

F. Mylius and O. Fromm—On the Formation of Floating Metal Sheets by Electrolysis.—*W. A.*, vol. 51, No. 4, p. 593.

THEORY.

A. Cornu—Electro-magnetic Synchronisation.—*Bull. Soc. Int.*, vol. 11, No. 107, p. 157.

D. Korda—General Problem of Closed-Circuit Transformers.—*C. R.*, vol. 118, No. 16, p. 864.

P. Duhem—On Hysteresis and Permanent Deformations—*C. R.*, vol. 118, No. 18, p. 974.

A. van Thyn—Stationary Electric Waves in Flat and Bent Plates.—*Beibl.*, vol. 18, No. 4, p. 462.

P. Duhem—Electro-dynamic and Electo-magnetic Effects.—*Ibid.*, p. 479.

H. A. Lorentz—On Electricity and Ether.—*Ibid.*, p. 482.

W. Voigt—Contributions to the Molecular Theory of Piezo-Electricity.—*W. A.*, vol. 51, No. 4, p. 688.

L. Baumgardt—Volta-Induction and Movement of Masses.—*E. T. Z.*, 1891, No. 17, p. 237 (I.).

VARIOUS.

J. Kerr—Experiments on a Fundamental Question in Electro-Optics: Reduction of Relative Retardations to Absolute.—*Phil. Mag.*, vol. 37, No. 227, p 380 (I.).

G. M. Minchin—Graphic Representation of Currents in a Primary and Secondary Coil.—*Phil. Mag.*, vol. 37, No. 227, p. 406.

J. Janssen—Electric Method of Heating Gases.—*C. R.*, vol. 118, No. 15, p. 757.

E. Bouty—Capacity of Polarisation of Mercury, and Capacities in general.—*Ibid.*, No. 17, p. 918.

A. Liénard—Pressures in the Interior of Magnets and Dielectrics.—*Lum El.*, vol. 52, No. 14, p. 7, No. 15, p. 67.

Anon.—Lamp Filaments Impregnated with Oxides.—*Ibid.*, p. 33.

Q. Majorana—On the Rapidity of the Photo-electric Effects of Selenium.—*Ibid.*, p. 40 (I.).

J. Blondin—On Double Electric Refraction.—*Lum. El.*, vol. 52, No. 16, p 101 (I.).

P. Hoho—Calorific Effect produced by the Electric Current at the Contact of a Liquid and a Solid.—*Ibid.*, No. 16, p. 113, No. 17, p. 165.

H. Luggin—On the Potential of Metals after very Short Contact with Electrolytes.—*Beibl.*, vol. 18, No. 4, p. 463.

C. Somigliana—Researches on Deformation and the Piezo-electric Phenomena in a Crystalline Cylinder.—*Ibid.*, p. 464.

L. Sieertzema—Dispersion with the Magnetic Rotation in Oxygen.—*Ibid.*, p. 468.

O. Humburg—On the Electro-magnetic Rotation of the Plane of Polarisation of certain Acids and Salts in different Solutions.—*Beibl.*, vol. 18, No. 4, p. 470.

P. Zeemann—Measurements in connection with the Kerr Magneto-optical Effect connected with Polar Reflexion on Iron, Cobalt, and Nickel.—*Ibid*, p. 472.

NOTICE.

1. The Institution's Library is open to members of all Scientific Bodies, and (on application to the Secretary) to the Public generally.

2. The Library is open (except from the 14th August to the 16th September) daily between the hours of 11.0 a.m. and 8.0 p.m., except on Thursdays, and on Saturdays, when it closes at 2.0 p.m.

An Index, compiled by the late Librarian, to the first ten volumes of the Journal (years 1872-81), and an Index, compiled under the direction of the Secretary, to the second ten volumes (years 1882-91), can be had on application to the Secretary, or to Messrs. E. and F. N. Spon, 125, Strand, W.C. Price Two Shillings and Sixpence each.

JOURNAL

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Institution of Electrical Engineers.

Founded 1871. *Incorporated* 1883.

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The Two Hundred and Sixty-fifth Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, May 10th, 1894—Sir David Salomons, Bart., Vice-President, in the Chair.

The minutes of the Ordinary General Meeting of April 26th were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Robert Arthur Dawbarn. | Joseph Shepherd.
Thomas Saville Watney.

From the class of Students to that of Associates—

William Dickinson. | John Clarence Lyell.

Mr. J. Rance and Mr. E. L. Berry were appointed scrutineers of the ballot for new members.

The Chairman: Mr. Crompton has a few more remarks to add to his paper, and the discussion will then be resumed.

Mr. Crompton.

Mr. R. E. CROMPTON: The diagram B is the one referred to on page 427, giving a 24-hours test of the Chelmsford power station. It is interesting from many points of view, but chiefly as showing the extent that the boilers of the works J in the paper can, when worked under the careful supervision of a test, show efficiency in excess of the annual figure of 5·2 lbs. of water evaporated per lb. of fuel. It will be seen that under the careful conditions of this test the evaporative efficiency rose to 9 lbs. There is no doubt that if we could arrange to fire at the same rate and exercise the same supervision throughout the year as we did on this one test, we could greatly raise the evaporative efficiency of these boilers; but there is no doubt that some approximation to the same result can be arrived at in a less expensive manner by the addition of a large economiser, which will take up a very considerable proportion of the units which are wasted when the stokers are not working their dampers and managing their fires in the most efficient manner.

General Webber.

General WEBBER: The great interest that this paper has excited will no doubt leave, as Mr. Raworth said at the last meeting, a deep impression on all those who heard it read; but I am one who, after having done so carefully, feel that much which is contained in it is open to criticism, and perhaps even to sharp criticism. Before proceeding to some remarks—especially on Table VI.—I would ask Mr. Crompton why he selected 5,000,000 units of energy sold per annum as an example for his ideal works. At 13 units per annum per 8-C.P. lamp, costing 8s. 6d. joined up, this means 384,615, and 18 units costing 12s., it means 277,777 lamps, or their equivalent. He tells us that his paper was framed after careful consideration of the results of the various known systems, and therefore I must assume that he was dealing with a load altogether for lighting purposes. The capital expenditure he allows works out either £1 6s. or £1 16s., according to the above consumption. Now I should like to remind him that in Kensington, the part of London with which he is best acquainted, by far the greater part of the load is for supplying light, and the average lamp earnings are less than 8s. 6d. Bearing that in mind, I am at a loss to know on what

General Webber

system, especially in the metropolis, Mr. Crompton framed his possible estimate. For instance, Kensington, which includes a small outlying portion of Westminster, is supplied by three companies, and according to the published returns of the last day of 1893 we had about 108,000 (8-C.P.) lamps joined up, and a capital expenditure of £3 per lamp. I would ask Mr. Crompton, does he think—especially as regards two of the companies, with which he is well acquainted, and which we believe, or, at least, we must hope so, are on the road to that ideal—he is going to reduce that £3 to £1 6s.? If he thinks so, does he forget that of the 100 miles of frontage, which will probably be the ultimate area which will have to be lighted in Kensington, only about four miles of street have mains laid along both sides? Does he believe that when the total plant of those three companies, which now has a capacity of about 2,300 E.H.P. output, reaches the 13,500 E.H.P. output, or thereabouts, which two (8-C.P.) lamps installed per yard of frontage, or 350,000, would require, that he will then come down to a capital expenditure of £1 6s. per lamp?

I shall next observe that Mr. Crompton's classification is between direct and conversion systems.

As I suggested in a paper read here in January, 1891, if there is any true classification, it is based on the question of the "frequency" of the sources of supply, irrespective of whether these sources are generating or converting. Mr. Crompton says that he has excluded the "mixed systems" from his tables, and yet he includes Chelsea, quite the most mixed direct-current system in the kingdom. This he has no excuse for ignoring if he reads the *Journal* of the Institution and the technical papers.

In his paper he takes up the position of an independent observer, compiler, and recorder of the results of a number of companies. Let us analyse the value of these records and conclusions. I should not have canvassed this question had Mr. Crompton confined himself to special reference to the Kensington and Knightsbridge, Notting Hill, and Chelmsford Companies, and what they have done and are doing, with which he is doubtless well acquainted. But he tells us that he has asked for the information he wanted, and obtained it (in some

General Webber.

cases anonymously), from the engineers of the other companies. When they decline to give it to him he assumes they can't give it, and he then calculates it. Table VI., which is the one on which some of his conclusions as to cost are founded, is as misleading as a table constructed in such a way can well be. His letter to the several engineers was headed, "Cost of Electrical "Energy," and he informed his correspondent that the date of reading his paper on that subject before the Institution had been fixed for the 12th April. The additional time thus accorded enabled him to supplement the data that he had already obtained. He told them that he had prepared a table showing the cost of fuel, cost of stores and water, cost of labour and salaries, per unit sold, for 20 of the most important electric supply works; that he had filled in these figures from the published accounts; and he asks his correspondent to supplement his compilation by correcting them if they are wrong, and by adding further information. He has not told us what he would have done if additional time had not been accorded to him. Would he have filled in his table by an approximate calculation for all? Without asking the engineers if they agree in "efficiency of distribution" being equal to units sold, plus units used in works, divided by units generated, he simply tells them that his measure of it will be on that basis, and winds up by telling them that if he does not receive it in time he will be obliged to fill in his table by an approximate calculation from the published figures.

Upon the replies or no replies to such a letter he has framed his Table VI. The meeting should entirely sympathise with the engineers who declined altogether, or, while not declining, gave partial information. Putting on one side what might have been the views of boards of directors (with which I sometimes differ), it is clear that none of the engineers who cared to be parties to the construction of a really valuable return, which was to go out to the world from this Institution, would think of doing themselves or their companies the injustice of helping to frame such a statement as Table VI.

Besides which, inaccuracies must inevitably exist even if a real intelligent comparison is entered upon, due to the wide

differences in each area of operations. I cannot conceive Mr. Crompton's having put his name to anything of this kind unless he is careless of his reputation as an authority. General Webber.

Although he distinguishes between systems which are alternating, continuous, and mixed with high and low tension, he does not take into consideration whether the load is large or small, whether the demand is dense or sparse over a given area, or whether the supply is constant or intermittent; and, lastly, while admitting a wide difference of price, and of the calorific value of the various coals used, he actually does not attempt reduction of these to any common standard for purposes of comparison.

His figures under the headings "Efficiency of Distribution" and "British Thermal Unit per Watt-Hour Generated" are even less instructive when they come to be analysed.

It will be observed that his question to the engineers dictates that their "efficiency of distribution" is to be measured by "units sold, plus units used in works, divided by units generated." No wonder some hesitated to answer his question. The result may be a measure of something, but I deny altogether that it has a right to be a measure of efficiency, for the reason that losses which arise out of conditions that save interest on capital may in themselves be a sign of efficiency.

I shall give an instance, namely, Chelsea, where by the published returns the capital expenditure is £2 8s. 8d. per lamp joined up. In that case Mr. Crompton had access to the information which I gave in 1891, when I told this audience that the losses at that time between the sources of supply and the consumers' meters, for both forms of conversion, was 30 per cent., while those within a radius of 250 yards of the generating station were reduced to a maximum of 10 per cent. with full load on the direct-driven continuous-current generating units.

Instead of 62, his self-estimated figure should, with the information before him, therefore have been at least over 70. Since then, the gradual increase of current generated and distributed without conversion, and of current converted during busy hours, with converter motors having 95 per cent. efficiency

General Webber. together with the replacing of small feeders (or "stems," as I then called them) by larger ones, has reduced those losses to a figure which will not be certainly over 20 per cent. Yet he deliberately tells the world in his draft proof that the Chelsea Company is wasting 38 per cent. of its current. When he read his paper I understood him to qualify this; but, as 62 per cent. is clearly obtained by the proportion between the figures in his third and fifth columns, it matters little whether he withdraws 62 or not, as long as he leaves 142 in the one and 88 in the other.

Where did he get 88 from? Indeed, considering that in his letter to the engineers seeking for information he asks no question which would give such information, I am at a loss to understand where he gets the figures in his fifth column.

Then, again, he has to admit that his third column has largely to be estimated by column four. I shall quote his words: "This difference" (*i.e.*, that between one system and another) "is made up very considerably by the difference of 'efficiency in "distribution;' I have calculated the actual fuel consumption at "the terminals of the dynamo by the efficiency of distribution "of the two systems."

I leave the meeting to form the only opinion which is available as to the accuracy of 142.

No one attempts to gainsay his statements about Kensington, Knightsbridge, or Chelmsford, but I for one altogether repudiate his being in a position to give any figures as regards the other examples.

At the same time, we should be interested in knowing whether Kensington and Knightsbridge stations serve the same or separate and distinct networks of mains, and whether either station occasionally or daily takes the whole load. A knowledge of this might go far to explain the results in their case.

Now, as regards Mr. Crompton's figures for ideal work, I have no patience, and I hope the meeting this evening will run riot with them.

But, unfortunately, they have been printed, and will go out to the world with the authority of Mr. Crompton, and the ignorant

will be carried away by the glamour of them, and it will be said that soon Mr. Crompton will provide electricity on those terms; indeed, I don't know if it has not been given out to all the municipalities that he will do so to-morrow. General Webber.

The worst of it is that Mr. Crompton deliberately tells us that we in London, for instance, may hope at no distant period to reach a condition of things under which, while selling current at 3d. a unit, the profits will be 1·68d., or 66 per cent.

What is to be done to our friend who (we hope thoughtlessly) spreads abroad such a statement as that, after having first told us that the average load-factor of the London stations is still a long way off rising above 20?

Mr. MARK ROBINSON: I wish to remark upon a few points only in Mr. Crompton's interesting paper, leaving to others better qualified than myself the appreciation of its merits as a whole. It is a most practical paper, and one of great importance. Mr. Crompton has shown us in time past that, if he is occasionally ahead of his times in what he says, his predictions—or some of them at any rate—have come true, and I hope this may be the case with the 2·5 lbs. of coal per unit sold. At the same time, I should like to say a few words upon the basis of that calculation, though without desiring to suggest that the calculation is widely wrong, if it is wrong at all; but there may be instruction in reviewing the figures a little. It rests on three factors, amongst others—viz., first, an evaporation of water by the boiler of as much as 12 lbs. per pound of coal; secondly, on the consumption by the engine of only 12 lbs. of steam per I.H.P.; and, thirdly, on such a small engine friction as to allow a combined engine and dynamo efficiency of from 86 to 88 per cent. With regard to the boilers, it is only necessary to say that 12 lbs. evaporation per pound of coal—or 10 lbs. in ordinary work, including all losses—is beyond our present practice; but we are all improving, and perhaps we may improve up to this. Mr. Crompton referred especially to the dryness of steam from water-tube boilers, and I would like to say that my company has lately taken up a French water-tube boiler, from which we hope great things, and from which we do actually get dry steam. Mr. Robinson.

Mr. Robinson. Thames Ditton has perhaps been responsible for some unfaith in times past in regard to the possibility of getting dry steam from water-tube boilers; but for many months past we have had a Niclausse water-tube boiler under test there with extraordinary results as regards dryness, there being less than ½ per cent. of moisture at the full intended rate of evaporation. Mr. Crompton has said that in his experience of the Babcock boilers he has been able to force them very much beyond their rated capacity, and they still give dry steam. We have had just the same experience with the Niclausse boiler; it has been driven at *more than double* its rated evaporation, and still there has been less than 1 per cent. of moisture. It should also be said that about the same time we had a Babcock boiler under test at Thames Ditton, and the results, as regards dryness of steam, were practically the same as with the Niclausse boiler. As we have spoken on this subject before in an opposite sense, some recantation is due from us. Though we have proved that our own boiler gives dry steam, it would not be honest not to say that, so far as we can judge, any other good water-tube boiler should give dry steam also; we do not claim it for our own in particular. So much, in the opinion of many, depends upon the success of water-tube boilers in the future, that I believe this testimony to their efficiency may be acceptable.

The next point is engine consumption, which Mr. Crompton takes at 12 lbs. of steam per I.H.P. This figure has, it is stated, been reached by the Sulzer engine. One could wish that the figures were corroborated by concordant results from a good series of progressive trials, or that at least they had been often repeated; but it would be unreasonable in the case of a large engine, which can only be put under full or even partial load when under ordinary working conditions, to expect it to be tested as we can test a smaller engine at Thames Ditton. Fortunately, the undoubted competency of the experimenters in the case of the Sulzer trials commands our full confidence. 12 lbs., then, and less than that, is recorded on good authority as having been reached by the Sulzer engine. Mr. Willans's best experimental

figures at Thames Ditton were 12·8, and the best actual guarantee we have given is $13\frac{1}{2}$ lbs. That was with a large mill engine of 500 H.P., and probably it includes a good margin. I have little doubt that, by carrying expansion much further, by jacketing to the utmost, and by carrying out every refinement possible, we could bring the consumption of the high-speed engine as low as that of the Sulzer engine; but in doing so it would be necessary to make a larger engine, with larger cylinders and pistons, and therefore having more ring friction, and of course at a greater cost. With the larger ring friction there would be a smaller brake efficiency, and hence a smaller combined efficiency in engine and dynamo together. It is to be feared the combined efficieney of 86–88 per cent. on which Mr. Crompton relies would not in that case be forthcoming. This is the point I wish to bring out; you cannot have your cake and eat it too. For extremely low steam consumption you want an engine with large cylinders and comparatively large ring friction, and that is antagonistic to a very high combined efficiency. On the other hand, if you seek a very high combined efficiency, you want an engine with little friction, and that is usually inconsistent with a high rate of expansion and extreme economy. You must not, in fact, take the lowest steam consumption *and* the lowest engine friction, and expect to get both in the same engine. Mr. Crompton's paper, I am aware, deals with the future. We are all improving, and we may come to his figures—perhaps to the best of them—but we are not quite there yet, for you must not expect to get at present both maximum steam economy and minimum friction. Mr. Robinson.

Mr. Raworth said that, although the Willans engine has certainly a good brake efficiency, $89\frac{1}{2}$ to 90 per cent., other vertical engines have the same; but so, he added, has every other; in fact, the ordinary vertical engine, he told us, has 92 per cent. efficiency, and thus the credit generally given to the Willans engine for specially high brake efficiency is undeserved. This is good news, for other people; but one would like to hear how he arrived at it. Compound or triple-expansion engines of large enough size to be worth discussing are not

Mr. Robinson.

easy to handle on brake trials, and few people are lucky enough to have sufficiently powerful brakes to deal with them. I presume in Mr. Raworth's case, and certainly in many other cases, where engine friction is talked about, reference is made to friction cards—that is, to diagrams taken when the engine is running light. But it is not certain, because you have taken a friction card from an engine running light, and have found it to show 8 per cent. of the full power, that therefore the friction of that engine *when fully loaded* is only 8 per cent., and its brake efficiency 92 per cent. The late Mr. Willans showed that in his engine the friction loss is approximately constant at all loads; for when coupled to a good dynamo the loss of the two together is approximately constant, and it is not to be supposed that the dynamo losses diminish as the load increases. But there is no certainty of a like result with a double-acting engine. There are four principal causes of friction loss which an ordinary engine suffers from. In the first place, there is the friction of the piston rings and valve piston rings. That certainly is practically independent of the load. Then, secondly, there is slide valve friction, which in most instances rises rapidly with the load, unless there is a very good system of balancing. That source of friction the Willans engine is of course exempt from. Thirdly, there is bearing friction; but where the bearings are actually working in oil, as in the Willans engine, this loss does not appear, according to the trials we have made, to alter materially with the load; in the double-acting engine, where the bathing with oil is less complete, we believe it does increase with the load. Fourthly, there is some loss of power due to "hammering" in the brasses of an engine in which the thrust is not always in the same direction, due to what the Americans call "lost motion." We do not know what its amount is, but there is little doubt that such a loss exists, and increases with the load; obviously, however, it does not exist in the Willans engine. Thus the single-acting engine has only sources of friction which are constant, or approximately constant; whereas the engine to which Mr. Raworth has compared it has also causes of friction which increase with the load. Therefore I am not

able to accept friction cards as conclusive of brake efficiency. Unfortunately, in suggesting that others are more or less theorising on this subject, I am theorising myself, and it may be of interest to Mr. Crompton and to Mr. Raworth and others to mention that we hope to bring this point to a practical test before long with really large engines. Our friends Messrs. Mather & Platt are about to put in hand for us one of those water brakes, such as Professor Osborne Reynolds uses (which are free from many of the difficulties which are supposed to interfere with the accuracy of certain forms of strap brake), large enough to absorb from 700 to 1,200 H.P., and upon which we hope to be able to run our largest engines. With regard to smaller engines, the mean figures of four brake tests made under full load at Thames Ditton upon a brake made on Mr. Halpin's plan (which also gives reliable figures) gave a brake efficiency of 90·6 per cent. The four engines ranged in power from about 60 to 160 I.H.P., and all were new and stiff, and certainly would have given better results after a few weeks' running, and therefore would surpass the 91 per cent. which Mr. Crompton has given as the best practice, and which I believe is very good practice indeed. Mr. Crompton makes an excellent suggestion in regard to the use of a pressure gauge on the steam chest. If people knew how much information they might get from it, and how much it would help them to watch what their engine is doing, they would always use such a gauge. In the days before electric launches, we had a pressure gauge on the steam chest of every launch engine, and you could tell by looking at it how fast your boat was travelling; you could set the speed quite accurately by the pressure gauge. To give the same advantage with automatic gear, we are arranging a pointer to show the exact position of the cut-off at every moment: this will equally (with a known steam pressure and speed) be an index to the power given out at the time. Mr. Robinson

Mr. W. GEIPEL: I join with others in eulogising the paper now under discussion, which contains information of the greatest interest and importance to those engaged in electricity supply, Mr. Geipel.

Mr. Geipel. more especially as it comes from one whose experience in central station working is unique. That the cost of supply should be within measurable distance of 3d. per unit, including profit, is at least encouraging to those who have not given the subject of cost more careful attention; while at this figure the dictum pronounced by Mr. Preece that the electric light is the poor man's light could not longer be denied by the most conservative. But, Sir, I hope to show you that Mr. Crompton has been altogether too modest. Look at his ideal costs, and you will there see that out of a total of 3d. he has put 1·68d. to profit. A large portion of the paper is occupied in discussing the item coal, which in his ideal cost is put at 0·27d., or one-sixth the item of profit. I have ventured to place on the wall a diagram (Fig. A) showing the effect on the total

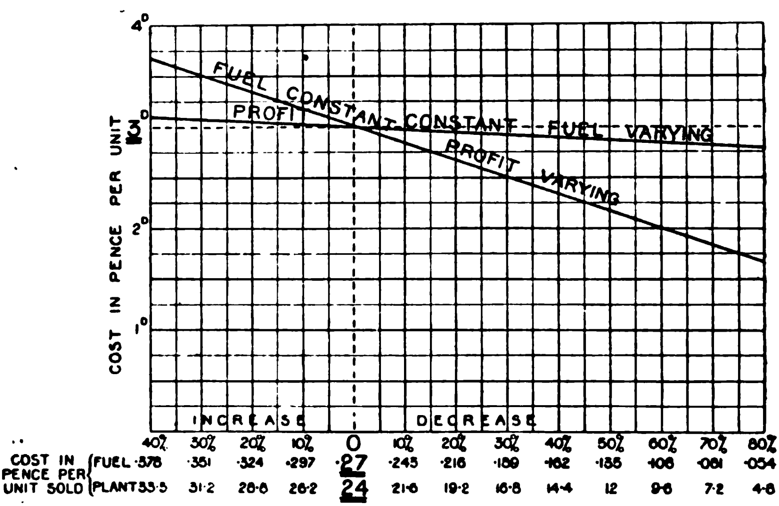

Fig. A.

cost of a proportional increase or decrease in the cost of these two items, from which you will observe that a range of 40 per cent. above to 80 per cent. below Mr. Crompton's ideal makes a difference in the price per unit of 0·35d. in the case of coal, against 2d. in that of profit. Again, I cannot imagine why Mr. Crompton is so eager in reducing salaries, wages, stores, and sundries to a mere fraction of what they at present cost, and yet

that he is content to leave the most serious item, profit—in other words, the first cost of the installation—to others. He says (on page 399) in speaking of this item, "We engineers have nothing "to say in controlling these figures." I do not for one moment agree with him in this. The reduction of the cost of electricity supply stations is very largely indeed the business of us engineers. In my opinion, the present high price of electric supply is due mostly to an insufficient consideration having been given to this question of first cost. It is certainly not always judicious to incur every possible expense in providing for saving in coal and labour and stores without regard to the consideration of outlay. For example, costly chimneys are frequently erected when a less outlay in this respect would suffice, or condensers and economisers are erected capable of dealing with the maximum load, the consequence being that a large portion is utilised but a mere fraction of the year. Is it not the function of an engineer to so lay out the capital that the cost of interest, depreciation, and the working expenses are together a minimum? Mr. Crompton does not say precisely how he arrives at his first cost of 2s. per unit sold per annum; but if his basis is the 20 per cent. load-factor to which he alludes further on, his figures mean a cost of £175 per kilowatt. It is my opinion that the first cost may frequently be less than one-half this figure—not, certainly, on the low-tension direct-current system upon which I fear Mr. Crompton has based his figures, but with the more modern alternate-current system, using high-tension feeders, supplying by transformers a low-tension network. I do not see why the improvements which are being made in the efficiency and the reduction of the cost of alternators and transformers should not enable us in future to arrive at a figure of £60 per kilowatt under favourable circumstances; at any rate, this is, I hold, very much nearer possibility than some of Mr. Crompton's ideal cost. General Webber gave us the figure £75 in a recent paper before this Institution as the cost of the City of London scheme, where there was unusual expense in the street work. Take even £80 per kilowatt, and apply Mr. Crompton's 20 per cent. load-factor, and his own figures for works cost and management, and we get—

Mr. Geipel.

Mr. Geipel.

	d.
Total works cost	0·5
Maintenance, 2 per cent. on 11d.... ...	0·22
Management	0·42
Profit, 7 per cent. on 11d....	0·77
Total	1·91

That is, less than 2d. per unit.

I am glad to hear that Mr. Crompton has recently become a convert to the alternate-current system, because I feel that, with further experience in the first cost of this system, and provided that he still stands by his ideal figures as to works cost, he will at a future day corroborate my figures of 2d. per unit. I am not so sanguine, however, as Mr. Crompton upon one or two points. A 20 per cent. load-factor is not often recorded in central stations in this country. Even 15 per cent. is considered good. Then, with regard to salaries and wages, he has taken these at 0·2d., or one-fourth of the average of the eight lowest records of the companies in *Lightning's* list; while water and petty stores he has at 0·03d., or one-fifth of the eight companies' average. I do not see how coal can possibly be reduced to 2½ lbs. per unit; but I believe 4 lbs. may be reached, even with English coal, which can be obtained in many towns at 7s. and less per ton, making the cost of coal 0·15d. per unit. Take, then, double Mr. Crompton's figures for petty stores, wages, and superintendence, and £60 per kilowatt: with a 15 per cent. load-factor we obtain—

	d.
Fuel	0·15
Water	0·01
Stores	0·04
Wages	0·20
Superintendence	0·20
Total	0·60
Maintenance, 2 per cent. on 10·9d. ...	0·22
Management	0·42
Profit, 7 per cent. on 10·9d.	0·76
Total	2·00

as what may be expected in towns favourably circumstanced as to load-factor and fuel, or other source of power, provided always they have had the foresight to adopt the alternate-current system. Mr. Geipel.

I am afraid that the figure Mr. Crompton has given us—namely, 12 lbs. of water evaporated at 150 lbs. pressure per lb. of coal—is one the attainment of which would gladden the hearts of legions outside the electrical profession. I am aware that under specially favourable circumstances, with the best fuel and

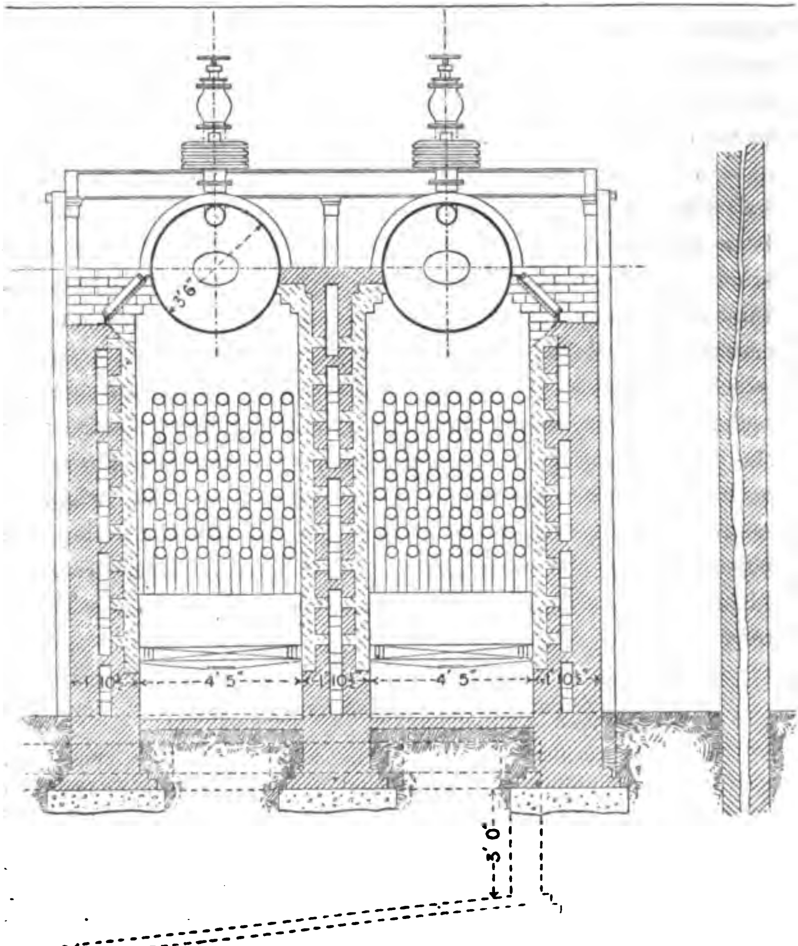

Fig. B.

Mr. Geipel. conditions, and deducting ashes, this result may be attained on occasion; but I have not yet found anything approaching this in practice, even under circumstances much more favourable than obtain in central station working. In fact, I observe that further on in his paper a lower figure—namely, 10 lbs.—is spoken of. At the same time, there cannot be a doubt that there is room for improvement, and perhaps I may be permitted to mention two methods of setting boilers which I have designed with a view to reduce the losses due to the radiation from the boilers, which are put out of use each night, diagrams of which are on the wall. One is applied to the Babcock-Wilcox boiler, which, as you are aware, is enclosed by a large amount of brickwork, absorbing, as Mr. Crompton points out, a proportional amount of heat. In order to reduce this I have introduced a thermal insulator in the form of an air space in the middle of the side walls, so that the outer half does not absorb as much heat as heretofore. This setting has been applied to the boilers at the Huddersfield and other electricity works, and has, I understand, been since adopted by Messrs. Babcock at other places, with good results. The other method relates to cylindrical boilers of the Lancashire and similar types, which I arrange as follows:—The gases, after passing through the boiler and under, are diverted into a main flue which leads on to the economiser; from this they pass by a large side flue round each boiler consecutively to the chimney; so that, whatever number of boilers happen to be out of use at any time, they are kept warm by the waste gases of those in use. There are other advantages in this type of setting, which, however, I will not refer to here.*

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* The following explanation of the diagram C may make the arrangement more clearly understood:—

Fig. 1 is a plan showing the setting, the boilers being removed. Figs. 2, 3, and 4 are sectional elevations. *a* is the main flue into which the gases pass from the internal flues; *b*, *b*, are the dampers for closing the main flue, *a*, from any of the boilers; *c* is the common return flue through which the gases pass from the main flue, *a*, by the economiser or feed heater along the sides of each boiler to the chimney, *d*. The arrows with tails show the course of the hot gases before they enter the main flue, and those without tails the course in the return flue. When adding an additional boiler it is necessary to change the baffle plates, *h*, from the positions shown in the plan in full lines to those shown in dotted lines: the gases

I do not agree with Mr. Crompton that the Lancashire boiler is unsuitable in all cases for electric lighting purposes, nor that its efficiency compares so unfavourably with other boilers. The comparison given on page 410 between the marine boiler at Glasgow and the Lancashire boiler tested by Bryan Donkin is certainly unfavourable to the Lancashire, but of all boilers the Lancashire is most unsuited for burning coke. It would probably be found that with bituminous coal the results would be reversed. Mr. Crompton speaks of a difficulty in utilising the hydrogen constituents of the coal. May I suggest that, provided there is an excess of the proportion of hydrogen above that required for combining with the oxygen already in the coal, there should be no difficulty with a suitable furnace in utilising the heat of combustion? I think it has been demonstrated that bituminous coal can be burnt under proper conditions without causing smoke; while the results of tests of the flue gases, so far as I know, do not show unoxidised hydrogen to any extent. There is this advantage with the bituminous or flaming coal—namely, that the heat is less confined to the grate. In other words, it enables a more gradual use to be made of the boiler-heating surface. At the same time, I quite agree with the author that anthracite coal has many advantages. I merely point out that there are numerous districts in this country where Mr. Geipel.

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in the return flue would then pass in the opposite direction along the sides of the boilers to that shown by the arrows; though in the main flue, *a*, and economiser the direction would remain the same. The greater part of the heat is taken from the gases for steam-making before they reach the main flue, *a*, while part of the remaining heat is employed in keeping hot those of the boilers which are not actually in use. The boilers not in use are closed from the main flue, *a*, by the dampers, *b*, while the gases from those boilers in use pass along the return flue, *c*, past the sides of those not in use. By making the return flue, *c*, large, the velocity of the gases is reduced so that they are as long in contact with the boilers as practicable. This reducing of the velocity also allows of more time for the depositing of unconsumed combustible, thus minimising the smoke emitted by the chimney. Another advantage of the large return flue is that the inspection or repair of the boiler is facilitated, and the flues are more easily cleaned. For example, the flue, *c*, at the sides of the boilers may readily be made of sufficient height to admit a man to walk upright along it. A by-pass flue, *e*, is provided from the main flue, *a*, direct to the chimney for occasional use when it is necessary to cool any of the boilers; and dampers, *f* and *g*, are provided for diverting the gases accordingly.

Mr. Geipel. bituminous coal can be used with far greater economy than anthracite or Welsh coal.

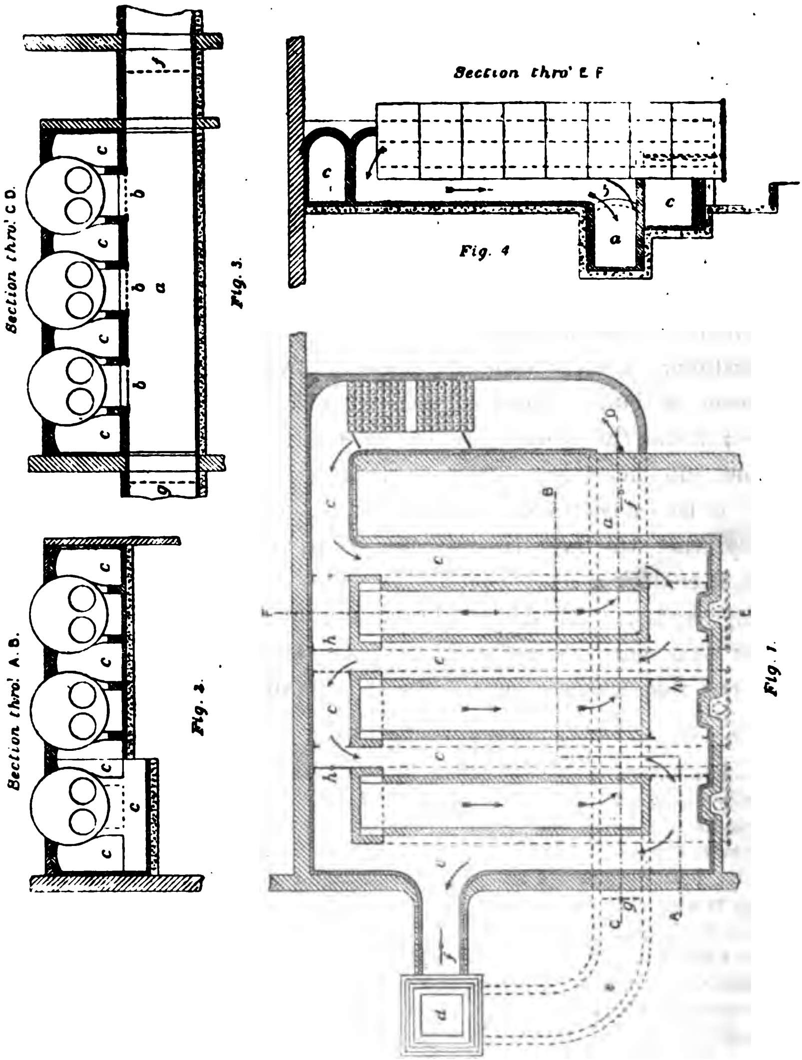


FIG. C.

I endorse most cordially what Mr. Crompton says of the Babcock boiler, and there are one or two important considerations in its favour which he has overlooked. The great

point which accounts for the suitability of this class of boiler is in the small quantity of fuel required for raising steam, which is largely due to the small proportion of water contained in the boiler. While in the Lancashire boiler there is as much as 0·8 cubic feet of water per square foot of heat surface, there is but 0·14 in the Babcock. Allowing for the greater evaporative power of the Lancashire heat surface, there are, for approximately every kilowatt of maximum output, 4 cubic feet of water in the Lancashire, against 1 cubic foot in the Babcock, to be raised to evaporating point daily. Each cubic foot of water requires about 1 lb. of coal to raise it from 212° Fah. to 366° Fah. So that with a 3,000-kilowatt plant, such as I take it Mr. Crompton speaks of, there would be about 12,000 lbs. required for the Lancashire, against 3,000 lbs. for the Babcock, for daily steam-raising. For steaming there would probably be required about 33,000 lbs. per diem with either boiler. The proportion, then, is for the Lancashire $\frac{12,000}{33,000}$, = 36 per cent., and for the Babcock $\frac{3,000}{33,000}$, = 9 per cent. only, for raising water to evaporating point; the net result being for the Lancashire 3 lbs., against the Babcock 2·4 lbs., per kilowatt-hour. I have used Mr. Crompton's figures for coal and load-factor in calculating the above. I am inclined to believe that there are cases where it would be advantageous to use a combination of Lancashire and Babcock boilers where bituminous coal is cheap, using the Lancashire continuously, and the Babcock for the top parts of the load curve. I do not think that in placing the Babcock and Economic boilers side by side on the score of safety, justice has been done to the Babcock boiler. In the Economic boiler, if I understand correctly, you have the internal flue, which is, after all, the most dangerous part of a boiler; while in the Babcock there is not only the absence of internal flue, but the parts of the boiler near the fire, and most susceptible to overheating, are tubes containing water, which could not cause an explosion. Mr. Geipel.

I am sorry to see that Mr. Crompton recommends the use of boiler fluids, &c., to keep the scale and sediment

Mr. Geipel. from affecting the surfaces; I am of opinion that the boiler is not the proper place to effect the deposit of mud and scale. The better cure is the removal of the impurities from the water before it enters the boiler. This can generally be done in the feed water heater or economiser: both carbonate and sulphate of lime, which are the chief impurities, are precipitated at about 260° Fah.; or the feed may be treated before it passes into the feed pipes with purifying apparatus.

Before leaving the subject of boilers, it may interest the Institution to know that in the year 1888 I made a test at the Lyceum Theatre, Edinburgh, with a view to ascertaining how much water could be evaporated at 150 lbs. pressure by forcing a 25 actual H.P. Babcock boiler, when I obtained about 6 lbs. water per square foot of heat surface; and I may mention that this boiler was running daily two 25-H.P. compound engines, and that without any excessive repair. Of course, when running on full load the efficiency was low, and I do not mean to advocate habitual overpressing to this extent; in this case there happened to be no option. This reserve power is, however, of enormous importance, for it enables the passing over of the peak of the load curve with a smaller quantity of boilers; and though at the moment of forcing there may be some loss of efficiency, it is probably more than counterbalanced by the saving in steaming further boilers, to say nothing of the saving in capital outlay in having less boilers to provide. I am glad to see this forcing advocated by Mr. Crompton, and I am of opinion that it may often be worth while providing blowing apparatus to be used during the heavy-load period, which, after all, represents a mere fraction of the whole year. On page 416 Mr. Crompton refers to the average efficiency of the existing alternating systems as 66 per cent.; but this is largely due to the use of separate transformers on scattered installations, where the same amount of money expended in distributing plant on the low-pressure system would have produced a most serious loss of potential and energy, certainly far exceeding the 44 per cent. spoken of.

It is interesting to know, as an example of the flexibility of the alternating system, that at Huddersfield they have already run

feeders out to the distant suburbs, where residential houses are being supplied; while in Bradford, where plant has been in operation so long, the suburban folk are still crying out for a supply. Even were the efficiency of alternating stations so low as Mr. Crompton puts it—though I do not admit it—we have merely to refer to the curves on the wall to see the effect of this question of fuel as compared with capital outlay. The result of banking the transformers is, however, making enormous improvements in this respect, and in Mr. Crompton's table this is instanced by the 82 per cent. of the City of London Company. I do not see wherein lies the difference in economy obtained by parallel running with continuous-current dynamos as compared with alternators. Mr. Geipel.

I am glad that Mr. Crompton advocates superheating the steam. I have for several years been an advocate of this practice; but instead of resorting to the use of superheaters, of which Mr. Crompton rightly points out the difficulty, why not evaporate the steam at a higher pressure, using reducing valves on each boiler? There is no difficulty in working a Babcock boiler at 200 lbs.; and if steam at this pressure be reduced to 150 lbs. pressure in the steam pipes, you will at once have approximately the 8 per cent. superheating mentioned by Mr. Crompton. The loss in the steam pipe is undoubtedly of the most serious nature, and every precaution should be taken to subdivide the steam pipes into sections controlled by valves, so that only that portion of the steam pipe which is absolutely necessary at the time being is used. The following rough calculations I have made may be of interest. Each square foot of lagged pipe when the steam is 300° Fah. above the atmosphere radiates 300 British thermal units per hour, which amounts to about 300 lbs. of coal per annum if in continual use. Uncovered surfaces, such as valves and flanges, radiate 1,000 British thermal units per hour, and require about 1,000 lbs. of coal, say half a ton, per annum. I do not know exactly what area of pipe there would be in Mr. Crompton's ideal plant, but put it at 3,000 square feet of lagged and 1,000 of unlagged pipes: this would require about 850 tons of coal per annum. Of course, by turning off the sections of the pipes not in use, this figure is materially reduced.

Mr. Geipel. Mr. Crompton speaks of the use of surface condensers as entailing the working out of several very difficult problems connected with the thorough filtering of the oil contained in the exhaust steam. Why use oil in the cylinders at all? It is a common practice in the mercantile marine, and Mr. Raworth never has a drop put into his cylinders, condensing or non-condensing. This is a very simple solution of the difficult problem.

I confirm all Mr. Crompton says as to the wastefulness of direct-driven feed pumps. My attention was first called to this about six years ago, when I made two six-hours tests on a 20-H.P. Babcock boiler. In the first case a Worthington pump was used, pumping from a tank overhead, in which the water was heated to 212° Fah., when 7 lbs. of Scotch coal were required per H.P.-hour. When using an injector, feeding from a cold water tank, there were only 6 lbs. of the same coal consumed per H.P.-hour. This is no doubt due, first, to the very slow piston speed at which these pumps work, and secondly, to the steam ports being full open to the end of the stroke. Since these tests, my company have designed a pump driven by spur gearing from a high-speed engine, from which very much more economical results are obtained. I cannot agree with Mr. Crompton that the losses in the feed pumps are due to the intermittent way in which they are worked; in fact, a feed pump ought to supply a continuous feed, as is generally recognised in boiler rooms.

I think it is probably a slip that has caused Mr. Crompton to state on page 427 that he has obtained at Chelmsford an efficiency of 76 per cent., which he says is as high as has been reached by any system of alternate-current distribution, while a few lines further on he gives the efficiency of the City of London Company as 82 per cent. In connection with this question of efficiency of distribution, I would point out that, while with the direct-current low-tension system this drops as the load-factor increases, on the transformer sub-station system the efficiency increases with the load-factor.

I have already exhausted your patience, but before concluding I should like to ask Mr. Crompton why he has not

taken advantage of the high thermal efficiency of gas engines in order to bring down his coal consumption. It is well known that less than 1 lb. of coal with gas-producing plant suffices to produce 1 H.P., therefore 1¼ lbs. per unit, or, allowing for losses in distribution, 1½ lbs. per unit, sold should cover fuel, as there is no loss in pipes due to radiation. My experience of modern gas plant shows that, considering the reduced cost of buildings and absence of chimney, the first cost is not far different from that of steam engines and boilers. As there is no difficulty in running alternators in parallel off properly arranged gas engines, the above figures are sufficient to show that there is at least potentiality in this source of power for electricity supply purposes. Mr. Geipel.

Mr. W. SCHÖNHEYDER: I think there ought to have been noted the rate of evaporation in lbs. per square foot of heating surface per hour. Without that it is impossible to say whether a boiler is economical or not. The other point I want to mention is in regard to water meters. It is of great importance that water should be measured for electric lighting stations, and Mr. Crompton has been good enough to refer to my meter. He states that it has been fairly satisfactory in its results, and I generally agree with what he says about it—I mean both for and against it. I know that the meter has in many cases given exceedingly useful and accurate figures, showing what the evaporation of water per lb. of coal has been, and the duty of electric lighting stations under various conditions; but I am also aware it has in some cases given trouble, and it is no easy matter to construct a machine which will work satisfactorily when the only lubrication you get is water that has been heated, and from which the lime has been separated. It (the lime) forms a very splendid grinding material, almost as good as emery, and for that reason some portions of the meter have given considerable trouble. But I have also instances where it has been worked satisfactorily up to 293 degrees, and shown practically no sign of wear; but in that case the water was exceptionally soft. The part of the meter which has given no trouble whatever is the valve face. There we have a kind of double—or eccentric—movement, which entirely prevents any cutting or galling; and the faces always remain Mr. Schönheyder.

Mr. Schönheyder. perfectly true and tight. In conclusion, I will just mention that I have arranged an improved meter, in which the whole of the seven rollers are entirely done away with; and I believe, as far as my experiments have gone, that it will get over the whole of the difficulties in measuring hot water.

Mr. Hammond. Mr. R. HAMMOND: I was very sorry to hear the ungenerous opening speech of General Webber, because those who are accustomed to put these statistics together are naturally those who know the very grave difficulties that beset anyone who starts out to do what Mr. Crompton has done. I regard this paper as one of the very best which have been prepared for the Institution for a very long time; and I think it is a very great pity that the opening speech of this evening should have been one that decried the paper, its methods, and its motives. It is impossible to believe that Mr. Crompton in collecting these figures was aiming at proving some particular point upon which he had made up his mind at the start. I would rather, on the other hand, say that the paper is a monument of diligence, and one for which we ought to be very grateful to Mr. Crompton. I was very pleased indeed to get an advance copy of this paper a few days before the last meeting, and I will take this opportunity of saying that I am sure all the members feel that that is a most excellent plan. In fact, I should almost feel inclined to go a step further, and say that if everybody had a copy of the paper there would be no need for the writer to read it—I mean, of course, that we could start off, as many other institutions do, by having the paper taken as read, and beginning the discussion right away. A fortnight ago the bulk of us had had the paper. Mr. Crompton did not do justice to the paper in reading it: he felt cramped for time, and he left out little bits here and there, thus making it somewhat disconnected; and if we had had the discussion a fortnight ago, perhaps some of us would have been very much happier.

With regard to the main point of Mr. Crompton's paper, we ought to be grateful to him for his prophecy of 3d. per unit—not 3d. per unit as the cost of production only, but 3d. per unit as the price at which we are going to deliver electricity to the consumers. One gentleman this evening has said that he thinks

it is a very great pity that those outside should be led to believe that, while being charged 5d., 5½d., 6d., and so on, 3d. is the correct price. I do not share those views. I think that the more we can make outsiders feel that this industry is on a basis where we can compete with every other illuminant, and compete with it not only in quality—which, of course, we absolutely do—but also in price, the quicker our fortunes as electrical engineers would be made. With regard to this 3d., however, it certainly is an alarmingly low figure—of course this is not reported outside; I am content for the 3d. to go outside. It is attained by a very large output. Threepence per unit on five million units is £62,500 per annum, and perhaps Mr. Crompton in his reply would inform the members how many towns in England at the present time have gas companies with such a revenue. And, mark you, since 3d. per unit is equivalent to, say, 1s. 6d. or 1s. 9d. for gas, and very few companies in the country charge as low as that—except Plymouth, which, I believe, is about 2s.—it would be fair to look out those whose income would be £80,000 or £90,000 a year: I think it would be found there were very few of them. Of course the question of the output is the crux of the whole question. In all these comparisons we do forget too often the question of output. It is impossible with any justice to compare the costs of two companies without taking the question of output in consideration first and last. I have been puzzling myself during the last two years as to how it would be possible to hit upon some method by which you could exclude the factor of output, but I have failed to get a solution. I think that the plan of finding out what the extra units cost—I mean the extra output of one 12 months, as compared with the preceding—does give one a bit of a guide towards the soundness of the costs of working. If it would be possible, having obtained a certain output, whatever it might be, to increase it by 10, 15, or 20 per cent., with only an increase of cost of 2½, 5, and 7½, then those works would be in an extremely sound condition; whereas, if an increase in the load of 10, 20, or 30 per cent. means an increase of cost—for those particular units, I mean—of 20, 30, 40, or 50 per cent., then indeed those works are in a bad way. Mr. Hammond.

Mr. Hammond.

Mr. Geipel referred to the average of some half-dozen, or dozen, or the whole of the companies in a certain list that he mentioned, and he drew the attention of the members to the fact of the very grave difference that existed between the ideal figures of Mr. Crompton and the figures as they actually appeared in that list. Here comes in the question of output. The basis of Mr. Crompton's paper is that some huge concern—probably only a few of the big London companies (the Westminster, possibly, and the St. James's: the Westminster's output bordered last year upon two million units)—should attain this output of five millions, and then when so attained it could manufacture at these low costs. But it is futile to compare with Mr. Crompton's ideal figure the figures of the companies in their to-day's position, many of whose outputs are as low as 40,000 or 50,000 units.

The next point of Mr. Crompton's system is omitting depreciation. Mr. Crompton's reply no doubt would be that he has made ample provision for maintenance, and that if ample provision be made for maintenance there is really no need to set up a depreciation fund. That is a doctrine that I should like very much to hold, but which I dare not; for one cannot shut one's eyes to the fact that even if there were no depreciation of plant, which probably would not occur if properly managed, you have antiquation of plant. There are some engineers who tell you that the particular plant they believe in will never be antiquated; but it is against the experience of engineering in the past, and —tell it not in Gath, nor to any town councillor—possibly some of the alternators or some of the dynamos in use to-day in certain modern stations will not be in use in those stations 10 years hence. I say "possibly," and if possibly, then do consider in making your estimate of cost the question of depreciation, which has been entirely omitted from Mr. Crompton's ideal figures. With regard to the capital account, Mr. Geipel told us that he was surprised Mr. Crompton said that it had nothing to do with costs. Well, it has very little indeed to do with costs of production; of course it has a great deal to do with the sinking fund, and it has a great deal to do with the interest that has to be paid upon it, but as a manufacturing implement the question of capital cost does not go very far into the calculation.

Mr. Geipel said that possibly we might reach the ideal figure of £60 per kilowatt. Well, it happens—because I notice in this Institution one is permitted to talk of one's own work—that at Leeds, where we began with only 250 kilowatts last May, and where the success has been abnormal, we shall finish this year with 900 kilowatts, only having begun last May. I say at Leeds our capital cost will not reach £60 per kilowatt, including all the central station plant, and all the mains that are at present laid down. I thoroughly appreciate Mr. Crompton's—hints, I was going to say, but I will use stronger words—the pioneer way in which Mr. Crompton points out to station managers how they can decrease their costs; but I do think, and I am sure you will agree with me—and Mr. Crompton too, though he makes little of it in his paper—that really the great secret of the cheaper cost of the future is in getting *by-uses* of the plant. Gas owes its cheapness, as we all know, to the very great value of its *by-products;* and I think we must agree that, if electricity is going to be supplied at 3d. a unit, it is on account of the value of its *by-products*, or, what is practically the same, the *by-uses* of the plant—uses to which it can be put in those hours—20, 21, and 22 very often out of the 24—when lighting is not called for. There is only one other point I want to mention, and it is just to stand up a little for some of the published data. Mr. Crompton said that he preferred to rely upon the information he got from central station managers. It is extraordinary, when you take up a balance-sheet, how very misleading it often is. I will back the published data, if it is properly audited, against the kind of information received from these central station managers. For instance, I have here picked out one or two balance-sheets that possibly Mr. Crompton may have seen before. With regard to Birmingham, I look at the central station costs there as set forth in the balance-sheet, and I find they are running the station without any engineering charges at all. I read in the printed return—"Proportion of "salaries of engineers, superintendents, and officers, as certified "by the managing director, chairman, or engineer, *nil.*" I happen to have had this balance-sheet given to me to dissect and analyse, and I cannot accept it. Mr. Crompton would take it for

Mr. Hammond.

gospel: it is so much prettier to look at, and comes out cheaper, and so on; but I take a more judicial view of it, and ask, Where have they charged their engineering expenses? I find them under Management, Salaries of Managing Directors, &c., &c., so that a certain proportion of them have to go back to the works costs; because I do not believe, although I have not been in Birmingham lately, that they are running the works without an engineer.

Mr. McLaren.

Mr. JOHN MCLAREN: I did not have the pleasure of hearing this paper read, but by the courtesy of Mr. Crompton I have been favoured with a copy, which I have read with great interest. I can join in the congratulations that have been offered to the reader of the paper for the very practical manner in which he has dealt with his subject. Those who know Mr. Crompton would not expect anything else. I am not an electrical engineer, but I am a maker of engines for driving electrical machinery, and as such I may be allowed to make a few remarks upon various matters which have been referred to in the paper. The cost of the electric light depends to a large extent upon the employment of economical steam generators and motors for the production of the current, and the measure of such economy is the amount of fuel and water required to give a stated result, and the cost of maintaining the plant in a state of efficiency. Boilers which upon evaporative tests have given a high efficiency may from various causes, such as the presence of water in the steam discharged, be far from economical in the consumption of coal per I.H.P. On the other hand, engines which give a good result from the point of view of the amount of steam used as measured by the indicator, may give a very low duty when the commercial test of the actual coal consumed is applied. I think it would be an advantage if, instead of the numerous independent tests of engines and boilers respectively, with the results of each given separately, we had more complete tests, in which the engine was tested in conjunction with its own boiler, and the net power given off was compared with the amount of coal actually consumed. It is not so much the best boiler or the best engine that we require, as the best combination, which may be a very different thing. Never-

theless, experience enables us to speak in general terms of the efficiency of certain types of boilers and engines, and it is in that connection that I wish to speak to-night. With regard to boilers, my experience shows that the locomotive type of boiler is the most economical steam generator extant; and if the fire-bars be placed at a suitable level, and sufficient grate area be provided, the difficulties with regard to cleaning the fires will be practically overcome. I think Mr. Crompton does this boiler a great injustice in putting the evaporation so low as 7 lbs. of water evaporated per lb. of coal. From 10 lbs. to 11 lbs. is more like the average evaporation, and in favourable circumstances an evaporation of 12 lbs. from and at 212° may be easily maintained. I believe the "Dry-Back" type of boiler to be a very good second, so far as evaporation is concerned; and where the boilers are fed with dirty water I would prefer it to the locomotive type. I am surprised that the Lancashire type of boiler is so often specified for electric lighting purposes. Unless it is supplemented by an economiser, it is comparatively a very poor steam producer. The heated gases escaping from the Lancashire type of boiler are stated in the paper with tolerable accuracy at about 700° Fah.; whereas those which escape from the locomotive type of boiler are more like 400°, or very little higher than the temperature of the steam itself. This shows the latter type of boiler is much better adapted for utilising all the heat than a boiler of the Lancashire type. I have had very little experience with water-tube boilers, but such as I have noticed have shown unmistakable evidence of turning out highly saturated steam. No wonder in that case that a high apparent evaporative duty can be shown! Mr. McLaren.

With regard to the best type of steam engines for driving the dynamos, the diversity of opinion amongst practical men is both surprising and puzzling. Each particular type of engine has its own advocates, and no doubt there are certain greater or less advantages connected with each one of them. But seeing that electricity as a means of lighting has taken its place amongst the facts of the age, and has evidently "come to stay," it surely

Mr. McLaren. "becomes those who are putting down plants to give due weight to the questions of permanency and cost of maintenance. Upon these grounds I think the high-speed single-acting engines will have to give way to larger engines, say from 100 to 200 I.H.P., running slower, and either driving the dynamos by ropes or belts, or having them of suitable size mounted upon a continuation of the crank-shaft. The high-speed single-acting engines, even when they are new and in perfect working order, have not by any means a monopoly of economy, and when they are allowed to get out of order they may be very wasteful indeed. Judging from such printed information as I have access to, the average economy both as to coal and stores has been far exceeded, if a record has not been attained, by the engines made by my firm for the Oxford Electric Light Company. These engines, when tested by Prof. Goodman and Mr. Wilson Hartnell with a load of 122 I.H.P., consumed 13·6 lbs. of water per I.H.P., including that condensed in the jackets, equal to a consumption of 1·35 lbs. of coal per I.H.P. per hour. Mr. Crompton, in Table VI., gives the B.T.U. per unit sold at Oxford at 88, whereas with certain other motors the B.T.U. amount to 300 or over. I attribute the great economy of these engines to the fact of their not only being triple-expansion, but surface-condensing. I believe the economy of condensation has been much overlooked, especially the advantage derived from its use when running with a low load-factor. This condition is one of serious loss with non-condensing engines, whether single-cylinder or compound, and I am convinced that the remedy lies in the more general adoption of condensation.

Mr. McLean. J. Hardie McLean: There are one or two points in Mr. Crompton's paper in which he criticises the Oxford system, and to which I should like to refer. Under the heading of "Stores "used in the Generating Station," Mr. Crompton states that the decrease in the stores rates in many companies has been very noticeable during the last few years. In the case of the Kensington Court works of the Kensington Company the stores have in some months reached as low a figure as 0·025d. per unit sold, and there is no doubt that even a lower figure will be reached as the output and load-factor improve. Mr. Crompton

is reported to have said, speaking of the efficiency of distribution: Mr. McLean.
"The Oxford figures came in at such a late period that I was "unable to mention them in the body of the paper. The results "are very encouraging; in fact, I think they are too good to be "true, especially when we come to consider the corresponding "use of stores in Table VII." Now in Table VII. Mr. Crompton gives 0·03d. as his ideal figure for water and stores. Kensington Court works have in some months got below this low figure. Why, then, should he discredit my statement that we have reached the figure 0·045d., which is still 50 per cent. above his ideal?

It is no argument because other central stations have not got so low that we in Oxford cannot reach his ideal by 50 per cent. I am quite prepared to substantiate any figures that have been published by the Oxford Company with reference to its system. Also, Mr. Crompton complains that he did not get his information from Oxford in time to be dealt with in the body of his paper. He got it almost by return of post when he wrote to me. When he makes the statement that our figures are too good to be true, he credits me with a quality which I hope I do not possess.

I think it would be very interesting if Mr. Crompton just saw this sheet on which we analyse our working every day: it is 4 feet 6 inches long, and contains 70 columns. A sheet of this description must be kept very accurately, or errors will creep in and render it useless. Similar sheets for last year were checked with the company's books, and found to be practically correct. There is another point in his paper about transformer losses which he thinks will be interesting to many to know—namely, that the circumstances under which they work at Chelmsford of supplying light between certain hours has enabled them to greatly cut down the transformer loss, so that they have been able to show an efficiency of distribution reaching 76 per cent. If we read a little further down the paper, we find that they do not supply the light for the 24 hours. It seems to me a pity that they do not get the light all the day round when they are paying for it. At Oxford we have a little bit of both high and low tension, you know; we can give you high tension and we can give you low tension, so to speak, and we give our consumers a continuous supply.

Mr. McLean. I think that, with the output we had last year of only 100,000 units, some of our figures in *Lightning's* list compare favourably with, if they do not beat, a good many of the best.

We are very small people down there, and we have to compete with companies having outputs many times greater than ours; but I think we hold the record in one or two items, and we mean to. I came here to-night to substantiate our published figures, and I am very glad to have had an opportunity of doing so.

Mr. Burnet. Mr. LINDSAY BURNET: I agree with those speakers who consider Mr. Crompton's a useful and valuable paper. I would confine my remarks to the subject of boilers. I consider Table V. to be most instructive, and that all steam users and boiler engineers are indebted to Messrs. Donkin for the careful work involved in preparing such; but, while admitting this, I would point out that since only one type of grate was used for the widely differing fuels, and that the efficiency varied so much, the practical values of the evaporation given in column 5 can only be taken as true for a given grate, boiler, and fireman, and not as standard values. With respect to such trials, which should be made in all large centres for the purpose of arriving at the practical values of the different fuels obtainable in the district, they cannot, to my mind, be complete without a chart showing the labour involved in the mere process of firing; and I have found that this item, taken alone, in many cases accounts for the great difference there sometimes exists between a trial result and everyday work. I think that in Table V. (*a*) a nice idea is put forward; but, unfortunately, the thermal value is not yet the true measure of cost, though in my opinion it is the duty and special province of electrical engineers to bring about the required change in this matter, just because they sell light and heat by a really truer standard than gas engineers, who buy their crude B.T.U. and pay for it according to analysis.

I sympathise with Mr. Crompton in his remarks on the mechanical disadvantage of the true locomotive type boiler with its small fire door, or doors, set some distance above level of fire-bars; and would mention that some years ago I designed and made a boiler of the locomotive type which has been, and is, successfully

used, and even with poor bituminous Scotch coal (fired by hand and also by machine). Mr. Burnet.

Mr. Crompton refers to the semi-marine boiler—which in Scotland is called the "Dry-Back" boiler—and to Messrs. Paxman's modification of it, called the "Economic." Perhaps, since my firm are the exponents of the "Dry-Back" type (though not the originators), I may be here allowed to state that the "Dry-Back" and the "Economic" are identical in type; they only differ in proportions and detail. While the "Economic" seems to work in to the ideas of those engineers who have been accustomed to smaller diameters and greater lengths, the "Dry-Back" comes in better for those engineers who must have larger furnaces, more room for internal inspection, and more simplicity and strength in the brickwork setting; and since we are within measurable distance of Government supervision of all steam boilers, the last two requirements are of considerable importance to the steam user.

No one will deny that the Babcock boiler has enabled steam users of a certain class to obtain high results. Good results have, however, invariably been obtained only with Welsh coal, or a coal with a high percentage of fixed carbon, comparatively pure water, and careful attendance.

The radiation, though relatively serious in the case of a single boiler of this type, cannot be of much account in a range of more than three boilers, if the ash-pit and damper doors are in order and properly worked. I am a little surprised to note how Mr. Crompton so lightly passes over the more or less difficult problem of cleaning these boilers. Of course it is purely a question of degree—*i.e.*, how bad is the water, how much boiler fluid is required, and how many T.U. are lost in blowing out.

I sympathise with Mr. Crompton in what he says about the good old servant, the Lancashire flue boiler, when designed and used for modern high pressures, and believe that if the care and intelligence of those in charge have not risen along with the pressures now carried, we might have some terrible accidents. If one glances over any insurance company's report and sees how much trouble arises from grooving, &c., in the ends and flues, even

Mr. Burnet. in the well-designed low-pressure flue boilers with lighter scantlings, one is apt to be sceptical as to the life of this type when built of heavy scantlings for high pressures.

With regard to the three types of steam generators mentioned in the paper—*i.e.*, the flue boiler, which may be taken as a slow-speed boiler; the tubular boiler, as a medium-speed boiler; and the tubulous boiler, as a high-speed boiler (speed in this case meaning rate of transmission)—I think that it is the duty of boiler engineers and makers now to analyse their merits as to efficiency at different speeds of working, just as the late Mr. Willans did so completely and carefully with his engines; also, that there is no simple answer to the question of what is the best boiler,—that there is no "all-round" best boiler,—and thus the boiler engineer must be supplied with full particulars (such as space available; output required, with a note as to the variation in rate of output, if there be any; qualities of water and fuel available or to be used, with their respective costs at the site), to enable him to do the best for the electrical engineer.

Yet it would appear that where higher intelligence is available, as at electrical light and power stations, a more or less high-speed boiler satisfies the conditions for commercial economy.

Tables III. and IV. are most instructive, and would show what great scope there is for still greater intelligence and care on the part of firemen; but I do not consider it safe to make such comparisons as Mr. Crompton does in calling your attention to the difference between Dr. Kennedy's trial at Glasgow and Bryan Donkin's in London, both with gasworks coke. This fuel has widely differing heat values, dependent on the qualities of the coal used at the gasworks, and also dependent on its state (*i.e.*, as to size, and also amount of water held) when delivered at site.

I agree with Mr. Crompton in respect to the use of forced or artificial draught, but would say that the fuel must be very cheap indeed where one could afford to use a simple steam jet for this purpose.

In conclusion, I desire to thank the President, Vice-President, and members of this Institution for their courtesy in having

allowed me to offer these remarks on a subject in which I take very great interest. Mr. Burnet.

The CHAIRMAN: Before adjourning, I have to annonnce that the scrutineers report the following candidates to have been duly elected:—

Associates:

Frederick Herbert Berry.	A. G. Jeffreys.
Arthur Carpenter.	Chas. Wm. Godson Little.
Harold William Couzens.	T. Blackwood Murray, B.Sc.
Svend Aage Faber.	Richard Wesley Olver.

William Turvey.

Students:

Ernest Cardin.	Gerald Graham.
Reginald Charles Carty.	Arthur Patrick O'Brien.
Walter Harding de Winton.	Robert John Strike.

The meeting then adjourned.

The Two Hundred and Sixty-sixth Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, May 24th, 1893, Mr. Alexander Siemens, M. Inst. C.E., President, in the chair.

The minutes of the Ordinary General Meeting held on May 10th were read and approved.

The names of new candidates for election were announced, and, this being the last meeting of the session, it was agreed that the candidates should be balloted for that evening.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

James Brockie.

From the class of Students to that of Associates—

W. E. Fowler.	Arthur Edward Langdon.
Montague Herbert Galsworthy.	Mark S. Poore.

Mr. Charles Bright and Mr. H. E. Mitchell were appointed scrutineers of the ballot for new members.

Donations to the Library were announced as having been received since the last meeting from Messrs. Whittaker & Co.; Professor H. S. Carhart, Foreign Member; and Professor S. P. Thompson, F.R.S., Member; to all of whom the thanks of the meeting were unanimously accorded.

The President: We will now resume the discussion on Mr. Crompton's paper, and, as several gentlemen have expressed a desire to speak, I hope the various speakers will endeavour to curtail their remarks as much as possible.

Mr. de Segundo.

Mr. E. C. de Segundo: There are so many points of great interest to which I think one might call attention in Mr. Crompton's very valuable paper, and as so many gentlemen have

spoken, and probably will speak, upon the essentially practical detail, I should like to confine my remarks to a brief consideration of what Mr. Crompton's "ideal possible" efficiencies really mean. In considering efficiencies in connection with a subject of this sort, I think it is wiser, perhaps, to compare the efficiencies with the best possible efficiency, rather than with the absolute efficiency. Mr. Crompton assumes in his "ideal possible" scheme that boilers can be made which will evaporate 12 lbs. of water at 150 lbs. per square inch per lb. of fuel. Now a boiler cannot do more than it possibly can, and in ordinary practice can only be expected to get somewhere near it. For the complete combustion of 1 lb. of average coal 10·7 lbs. of air are necessary; hence, altogether, 11·7 lbs. of gaseous products will find their way into the chimney. Assuming now that these products of combustion go away at 400°, and that they were allowed into the furnace at 60°, there would be carried away, roughly, 915 thermal units. That is absolute loss. This heat cannot be utilised in any way. Subtracting that from the 14,100 thermal units which may be taken as the calorific value of such coal as we are considering, the maximum possible evaporation per lb. of fuel becomes 12·8 lbs. of water at 150 lbs. per square inch pressure. Mr. Crompton's estimate of 12 lbs. per square inch, therefore, means a relative efficiency of $\frac{12 \times 100}{12 \cdot 8} = 93$ per cent. in the boilers; but we know quite well that it is not always possible to regulate the air supply so exactly that only the amount theoretically required for the chemical combustion of coal alone is admitted; and assuming that we admit 18 lbs. of air per lb. of coal consumed (which I do not think is too liberal an allowance), our maximum possible is reduced from 12·8 lbs. to 12·25 lbs. of water at 150 lbs. per square inch per lb. of fuel. Therefore Mr. Crompton's assumption of 12 lbs. now really means a relative efficiency of nearly 100 per cent. Mr. Crompton's figure might no doubt be realised with a better quality of fuel, but in any case it is worth while bearing in mind that it is an extremely high ideal which is set before us. As regards the engine, the author says in his paper that engines will, and can, be made for us which will give us 1 I.H.P.-hour per 13 lbs. of steam Mr. de Segundo.

Mr. de Segundo.

when loaded from half to three-quarters full load. I think those are the figures. Now, working that out in a similar manner, I find that 13 lbs. of steam at 150 lbs. per square inch contain nearly altogether 13,400 thermal units. 1 I.H.P.-hour is equivalent to 2,540 thermal units. Therefore Mr. Crompton's assumption amounts to a heat efficiency of 19 per cent. for the engine, which, I submit, is again a very high ideal indeed to look forward to in everyday work. Then, if we come to consider what one might reasonably expect in ordinary practice, and start with 1 lb. of good coal of a calorific value of 14,500 thermal units, we may, I think, reasonably assume 70 per cent. as the all-round efficiency for the boiler which can be calculated upon to be realised in everyday practice. If we subtract 10 per cent. for stand-by losses, we find that the thermal units in 1 lb. of coal have sunk from 14,500 to 9,140. From calculations based upon the results of actual work, I find that 10 per cent. is about the outside absolute efficiency which one can count upon for a high-pressure non-condensing steam dynamo—that is to say, the ratio of thermal equivalent of E.H.P.-hour to heat energy in steam per 1 H.P.-hour. Therefore that brings us down to 914 thermal units, which, if we subtract 10 per cent. for distributing losses, leaves 823. Now 1 kilowatt-hour is equivalent to 3,430 thermal units; therefore apparently we cannot hope to realise in practice a lower efficiency than about 4 lbs. coal of a calorific value of 14,500 thermal units per lb. per kilowatt-hour delivered to the consumer's terminals.

The next point which I think is worth a little consideration is this: The public do not understand anything about watts; they do not wish to buy watts,—they buy candle-power,—and they only think of the amount of light they get as compared with the bills they are called upon to pay. What engineers have to consider in attempting to popularise electric lighting, so to speak, is to bring it more and more nearly to the price of gas. The present efficiency boilers, engines, and dynamos leave comparatively little room for improvement; whereas there is a practically unlimited scope for invention and improvement in the distributing system, and, above all, in incandescent lamps. Now, if the incandescent lamp could be so improved as to give 1 candle-power for 2½ watts,

with the same percentage loss of candle-power and the same life as with 4 watts, it would be equivalent to bringing down the price of the electric light to the consumer from 6d. to 3¾d. per unit. By using the Robertson lamps at 2½ watts per candle efficiency, which are guaranteed not to lose more than 25 per cent. of the original candle-power during a life of 400 hours, the cost of the electric light, on the basis of light for light, is equivalent (including cost of renewals) to gas at 3s. 6d. per thousand cubic feet. Mr. de Segundo.

I cannot conclude without paying my personal tribute of respect and gratitude to Mr. Crompton—respect for his untiring zeal and painstaking research in the field of electrotechnics, and gratitude for his generosity in giving to all of us so admirably summarised an account of his wide, and indeed unique, experience in electric lighting.

Mr. JAMES N. SHOOLBRED: There are many points which Mr. Crompton has raised in his very valuable paper, but I wish only to touch upon one or two of them. Mr. Shoolbred.

With respect to what are termed in the paper "works losses," these losses are much more serious in amount than is generally supposed; and, moreover, they arise from causes which, as a rule, are much more easily preventable than is the case with those in the boilers, the engines, and the dynamos. These works losses appear to concentrate themselves in great measure within the connections between the engines and the boilers; and they seem in great measure to be due to variations in temperature, causing leakage and condensation in the pipes, and breakages in the joints. A great deal of the loss is due, apparently, to the injurious system, which is still followed in some cases, of extinguishing the fires, instead of banking them. The temptation to do this is greater with water-tube boilers than with others, owing to the facility with which the fires are extinguished and steam got up again.

I cannot follow Mr. Crompton when he says that Lancashire boilers seem to produce rather worse results than water-tube boilers; since in the water-tube boiler this extinction of the fires and the cooling down of this system of connections, and the

Mr. Shoolbred. consequent losses which arise therefrom, should also be taken into consideration.

In Table VI., and in other parts of his paper, Mr. Crompton treats of the relative economy of the various systems of "direct" (*i.e.*, low-pressure) or of "converted" (*i.e.*, high pressure—whether "alternating" or "continuous"), and of the various economies which the "direct" system presents, especially when "storage," by the use of secondary batteries, is included in it.

By the courtesy of the Bradford Corporation, I have been enabled to place on the table a number of ampere-output diagrams, extending over a period of four years; and which thus show the progressive working of that station. These diagrams indicate horizontally the time from midnight to midnight, and vertically the ampere output; and they indicate very clearly when the dynamos are providing the supply, and when the storage batteries are working unaided. It will be seen from the diagrams that there is a considerable period in the 24 hours during which the steam engines are stopped, and the supply carried on entirely by the storage batteries; resulting in a very sensible economy in wages and in coal, arising from such relief to the generating plant. During the three years that storage had been in use at Bradford, the average duration of the relief to the generating plant out of the 24 hours had been: In 1891, 12 hours, or 50 per cent.; in 1892, 10½ hours, or about 45 per cent.; while in 1893 this was reduced to five hours, or only 20 per cent., owing to the large increase in the demand; thus proving Mr. Crompton's statement that it was in the earlier stages, when the demand was small, that storage was especially valuable in a central station. One cannot, therefore, close one's eyes to the fact that, owing to the considerable economy in wages and in coal due to the use of storage, any system, whether "alternating" or not, which would oblige the generating plant to be run during the entire 24 hours, must naturally be more expensive in itself than where storage is used.

I have been enabled, likewise, to place before the meeting some diagrams which show the proportion of working expenses to the receipts, as well as the relative cost of coal, of wages, and of

water—in all cases extending over the four years 1890-93—and which represent the actual facts as taken from the accounts issued by the Bradford Corporation. Mr. Shoolbred.

It is interesting to note how, during the latter two out of the four years, the working expenses have kept nearly constant at about 50 per cent. of the receipts, and the working cost per unit at about 2½d.; thus indicating what might be termed the "working ratio of production"—a figure which will not be improved by extending, beyond a certain point, the radius of the supply. Thus confirming Professor Kennedy's remarks, that there is a limit beyond which it may become more economical to erect a second station.

Mr. Geipel in his remarks spoke of the proportion of the capital to per unit sold, which Mr. Crompton put at 2s., being in his (Mr. Geipel's) opinion an almost impossible figure, especially with continuous-current installations. Now the result of the working of the Bradford station in 1893 had been, that the proportion of capital expended was only 2s. 6d. per unit sold, and that even during the coal strike of the last half-year; so that 2s. might certainly be expected to be reached before long.

Mr. Hammond had also mentioned, that if the 2s. ever was reached, it would require a sale of millions of units before it could be done. But the low rate just referred to at Bradford, in 1893, had been effected on a sale of slightly under half a million units. It seemed somewhat anomalous to hear Mr. Hammond—supposed to be so wedded to "alternating" as not to think of anything except lighting—now state that it was in the "by-uses," as he termed them, of the energy, that the chief financial hopes of central stations lay. No doubt the economies effected at Bradford and at other similar low-pressure "continuous" stations by the use of storage, and of motor working, as well as of various other applications of that kind, were becoming appreciated by those who had formerly overlooked these advantages.

In conclusion, I must again thank Mr. Crompton, not merely for all the trouble he has taken in compiling a mass of very valuable and highly interesting information, but also for the economies which will no doubt follow later on, and which many

Mr. Shoolbred. of us will reap great benefit from, in the cheaper production of electrical energy.

Mr. Henwood. Mr. E. N. HENWOOD: Mr. Crompton has spoken of $2\frac{1}{2}$ lbs. of coal per I.H.P. per hour as being the ordinary work done in 1883. Of course he is perfectly well aware that during the last 10 years the consumption of coal in marine boilers has been reduced to 1·7 lbs. per I.H.P. with triple-expansion engines. Although people have still stuck to coal, no method has, even during the last 60 years, been devised by which *complete combustion* can be obtained with such a poor combustible as coal. There is invariably a loss of about 25 per cent. of incombustible ash; but, further, the system of hand firing by shovels is so crude, unscientific, and wasteful that it ought to be discarded. Mr. Crompton has expressed his opinion that the mechanical stoker is still more inefficient and wasteful. In this I entirely concur. But he passes over the grave loss occasioned by the heat imparted to the fire-bars, which has no useful effect, but, on the contrary, is destructive; and even with wood-burning in a steamer it was found that the ordinary cast-iron fire-bars were quickly burnt out. I am aware that recently some attempt has been made to use tubes filled with water as fire-bars, so as to utilise some of the heat; and great loss is occasioned by the constant opening of large furnace doors while firing up, thereby admitting such an excessive amount of cold air that the effectiveness is seriously impaired and the boilers are injured. I quite concur with the author's views when he says that it pays best to use nothing but fuel of the highest calorific value. And, further, he says, "We find very rarely that any form of furnace "now in use is able to utilise any considerable percentage of "these hydrogen units." In a properly constructed furnace these valuable units can be utilised to their full value, especially in an oil-fuel fired furnace; but time does not permit of going further into this subject. He then goes on to refer to the various types of boilers. I have no doubt the meeting is perfectly aware that at the Glasgow electric lighting station they have used the return tube boiler of marine type. While I am no advocate for any inferior type of boiler, I must say that, in my judgment, an

internally fired boiler is to be preferred to any other. At the same time, if an improved water-tube boiler be devised so as to dispense with fire-bars and a cold ash-pit, it will be an improvement to be desired. Mr. Henwood.

I am glad to find that the author speaks so well of the Babcock & Wilcox boiler, and states that it can be forced without priming. It is, of course, of primary importance to use pure water; and it is advisable to use a filter for the feed water to pass through, and so keep it free from impurities of any kind. Mr. Crompton further states that 9¾ lbs. of water have been evaporated per lb. of coal, and that the gases leave the boiler at a temperature slightly in excess of that of steam. It would be useful if he were to tell us the temperature of the feed water, and what means were employed to accurately measure the quantity—if by a water meter, or by tanks.

Then he goes on to speak of oil-fuel. I want to place on record that, in my judgment, it is utter loss to attempt to use coal when you are burning oil, because it will not add anything to the effect, but, rather, diminish the heat obtained from the oil. In a properly constructed furnace for burning oil-fuel the conditions are essentially different from those which are in operation when burning coal. In an oil-fired furnace you need to have the admission of air strictly under control, and be able to prevent any large accession of injurious air being drawn into the furnace, as is the very detrimental and unavoidable custom when firing with coal. Moreover, with a properly constructed oil-fired furnace you obtain complete and perfect combustion, entirely avoiding the nuisance of smoke, soot, &c., and the loss occasioned by the constant feeding and cleaning of the fires, which necessitates the door being frequently kept open.

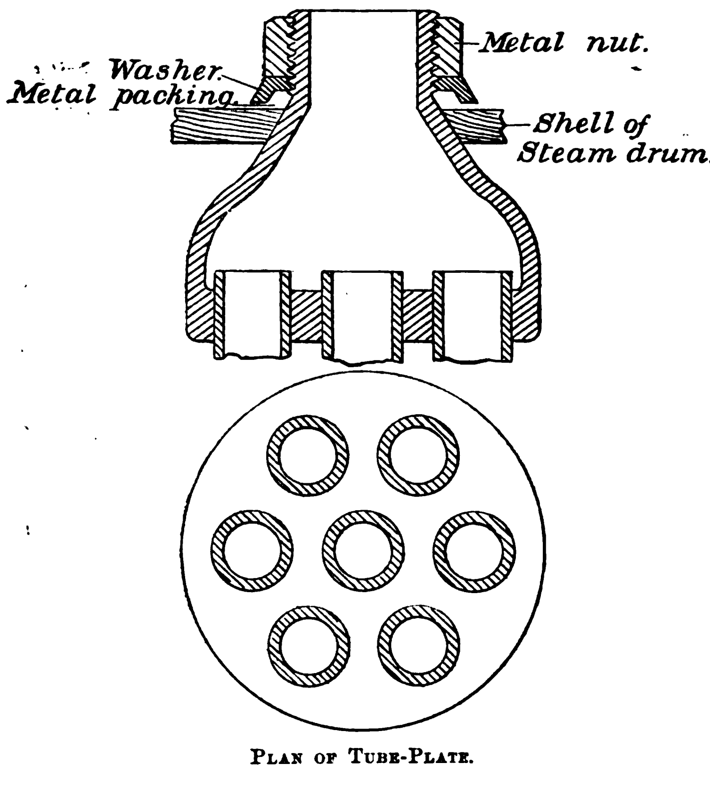
The author then makes various remarks on several types of boilers; and, with your permission, I would draw attention to an improved type of water-tube boiler known as Petersen's; and it is so far in advance, in point of value, of any other which has been devised, that, if the meeting will permit me, I will make a short sketch of it.

In this patent "compound-tube" there are seven tubes of

Mr. Hepwood.

$\frac{3}{4}$ inch diameter, connected to one "cup," or "header," of wrought iron or steel, and only one connection (by a coned metallic joint) of the neck of the "cup" to the steam drum, which neck, projecting through, is secured steam-tight by a metal nut.

Section.



Plan of Tube-Plate.

The "cup," or "header," is *shrunk* on to the tube ends; the tubes might be of any convenient length, with a cup at each end, and the *shrinking* on of the "cup" made such perfect connection that the tubes could not leak or be drawn out. The tubes were termed "compound tubes," and were so arranged that it was impossible for any incrustation to find lodgment, the circulation being so rapid none could adhere; and each compound tube could be readily removed and cleaned by hammering or warming over a fire. The boiler, it was maintained, was far superior in efficiency to any

other in existence, being constructed on sound mechanical principles. Only about one-ninth the number of holes now required will be necessary in the steam drum, in comparison with other water-tube boilers; and in comparison with the marine return tubular boilers the weight under steam will be about one-eighth, the space occupied and cost of construction about half. Mr. Henwood.

I will ask you not to be too incredulous when I tell you that with a reliable system of oil-fuel firing I have been able to effect an evaporation of over *three times* that which has been obtained by coal. You may argue that this is more than is known (by the laboratory tests) to be obtainable from the calorific value of the oil-fuel *per se*. It may be so; but then you have to remember that when you use superheated steam in connection with it, and with a proper amount of air, and do not deluge the furnace with an excessive amount of air, you will get far greater heat than many people would ever imagine it would give. It is so great that you can without difficulty melt fire-bricks into the consistency of honey.

In addition, I have had a Lancashire boiler, 30 feet long, with two furnaces, fired by oil-fuel only, for 28 days and nights continuously, giving perfect satisfaction; the attendant stating that it required no attention, his occupation being limited to keeping the water in the boiler at the proper level.

My steam yacht "Ruby" was continuously day and night under steam for over *four months*, worked on my oil-fuel system (to the complete exclusion of coal). It was approved of by the committee of Lloyd's, confirming their chief engineer surveyor's report; by the chief engineer surveyor to the Board of Trade; and the superintending engineer of the Great Eastern Railway Company, after some three hours' trial, voluntarily remarked "*he* "*could not have believed it to be so perfect if he had not seen it.*"

The advantages of oil-fuel are so numerous that I am afraid their enumeration would occupy too much space; but it will be admitted that the avoidance of smoke alone would be an immense boon, especially in large cities; it may, therefore, be interesting to inform the meeting that some of our electric lighting companies are about to test this system.

Mr. Henwood.

Finally, there is no danger of spontaneous combustion; and the fire insurance company were so satisfied on the subject that there has been no increase of premium, oil-fuel being perfectly safe in its normal condition, and as stored in bulk its temperature could not be raised to 300° Fah.

Mr. Dykes.

Mr. A. H. DYKES: The figures that Mr. Crompton has brought before us are of the utmost value in enabling us to judge the value of the different systems and the different pieces of apparatus. It is, however, important, before comparing different systems or different types of engines and boilers on the basis of these figures, to understand fully any special conditions that modify the general result. I therefore have pleasure in reading a letter which has been forwarded to me by Mr. Tonge, the engineer of the Preston Company, in which he gives a few details concerning that station. I do this the more readily because in Mr. Crompton's paper this is the only low-tension station mentioned in which double-acting engines are used, and it might appear at first sight that the comparatively low efficiency of the station might be due to the particular type of engine in use. Mr. Tonge writes: "Mr. Crompton, in his paper on the 'Cost "'of Electrical Energy,' has discarded the data as to the works "costs of the Preston station on the ground that they are "abnormal. As this statement is misleading, and apt to create "an impression that the works are unable to generate electrical "energy at a cost which will compare with that of other works of "similar output, I take this opportunity to place before you "some figures in the subjoined table showing the actual cost of "generation and distribution per unit delivered to the customer "for three periods—viz., January to June, 1893; July to Decem-"ber, 1893; January to March, 1894:—

Mr Dykes.

PRESTON ELECTRIC LIGHT STATION.

Cost of Generation and Distribution per Unit delivered to Customers.

	Jan. to June, 1893.	July to Dec., 1893.	Jan. to March, 1894.
Coal, &c.	1·25	1·94	1·062
Oil waste, water, and petty stores	0·51	0·28	0·181
Wages and salaries—generation and distribution	1·35	1·30	0·060
Repairs and Maintenance of			
Plant at station	...	...	0·178
Mains, services, & meters	0·31	0·30	0·116
Motors, arc lamps	...	...	0·300
	3·42	3·52	2·71

"It will be seen that, with the exception of the cost of coal, which is somewhat erratic, all the items show a distinct downward tendency; and the total works costs for January to March, 1894, are very satisfactory when the output is taken into consideration. The number of units delivered to customers in 1893 was 149,636. The cost of coal was largely affected by the coal strike, as will be seen by comparing the figures for the two halves of 1893. Coal is now costing us from 20 to 25 per cent. more per ton than in the early part of 1893, so that the figure 1·060 in the table for the first quarter of 1894 is really a considerable improvement on the cost for the corresponding part of 1893. I also think that Mr. Crompton's figure for the heat units per watt-hour at our works should be altered. Apparently no allowance has been made for the extra cost due to the coal strike, and therefore too high a value has been put on the coal used. In regard to the efficiency of distribution, which Mr. Crompton puts at 80 per cent., I am altogether at a loss to understand how he arrives at this value. In his letter of inquiry he asked me for the efficiency of distribution, taking this as being equal to units supplied to customers + units used by

Mr. Dykes. company ÷ units generated. The figures I supplied him with showed that for 1893 this works out at 93 per cent. Even supposing the efficiency of distribution be taken as equal to units supplied to customers ÷ units generated, the result works out at 86 per cent. Both of the figures are much better than the 80 per cent. which Mr. Crompton gives. In conclusion, I would observe that, as we have no batteries, our engines, &c., are run under conditions more nearly resembling those in an alternate-current works than in a low-tension station with batteries."

The reason why the station costs appear high is that the present company had to take over a number of contracts, with the Corporation and others, for running arc lamps, incandescent lamps, and motors, which are owned and kept in repair by the company, who also supply carbons and brushes. These costs do not really fall under the heading of generating and distributing expenses, and they have therefore been kept separate in the table. It will also be evident, on inspecting the figures, that the cost of coal was very largely affected indeed by the strike of last year; and it is peculiar that in the North, where the coal is very cheap, only costing before the strike 6s. 3d. or 6s. 6d., instead of 20s. or so, as is the case down here, they were affected by the strike considerably more than people in the South, the cost of coal being nearly doubled.

Mr. Tonge further writes that the combined efficiency of the engines and dynamos amounts to 82 or 83 per cent.; and, considering the sets are only about 100 H.P., I think they compare favourably with those of other types. The actual water consumption has been found in practice to be 27 lbs. per electrical H.P.-hour, non-condensing; and the coal consumption per unit sold 29 lbs.—a figure which may be of importance as showing the actual result obtained with small slack burnt in Lancashire boilers. The best consumption of coal for a period extending over three weeks in the winter amounts to 17½ lbs. per unit sold. Throughout the engines have given the greatest satisfaction, both as regards small expense of upkeep and steady running. There can be no doubt, of course, that these figures could be very largely improved by the use of a moderate amount of storage;

and it shows that even with an efficient generating plant, running day and night, with three shifts, on a comparatively light load, brings up the station costs very considerably indeed. It is only right, I think, that figures which greatly modify these published results should be brought before us, so that we can see exactly why it is that certain stations appear high, and what are the conditions which cause this comparatively high consumption. Mr. Dykes.

Professor W. C. UNWIN: I am afraid it requires some apology for a purely mechanical engineer to interpose in a discussion here, but my excuse must be that Mr. Crompton's paper shows how very large a part questions of mechanical engineering play in at least the finance of central station working. Mr. Crompton will not misunderstand me if, in the few minutes during which I shall occupy your time, I indulge rather in criticism than in acknowledgment of the great value of his paper. Professor Unwin.

Mr. Crompton makes some statements about the relative value of Welsh coal and coal of any other description. He admits that in calorimeter tests the North country coal is nearly as good as Welsh coal. I do not think there is any good evidence that the heating power of North country coal, as tested in a calorimeter, is at all lower than that of Welsh coal. But then it is urged in the paper that there is so much difficulty in burning the hydrocarbons of Northern coal that it is practically very inferior to Welsh coal. There were a very long series of tests carried out between 1860 and 1870, partly for the Admiralty and partly for other people, in which the broad general result, if you examined the tests carefully, was this—that there was no practical difference between the evaporative power of Northern coal and Welsh coal. It is the smokelessness, and not the calorific power, which gives to Welsh coal its great market value.

One other fact may be quoted. Professor Kennedy carried out a series of tests with marine engines on a very large scale. In the whole of that series there are three tests in which an evaporation was obtained of over 10 lbs. of water per lb. of coal. Those three were the only trials which gave a high evaporative efficiency. Two of these were made with Northern coal and one with Welsh. In the two trials in which the highest results were

Professor Unwin. obtained, one with Welsh and one with Northern coal—the "Iona" with Welsh coal, and the "Tartar" with Northern coal—the evaporation is practically identical.

The next point in the paper is this: An extremely unfavourable view is put forward of the thermal efficiency of Lancashire boilers; indeed, it is stated that a Lancashire boiler is only half a boiler, and that an economiser must be added to it before it makes a whole boiler. Of course there are a great many facts which one could quote controverting that, but I will only mention one. Some two or three years ago I had to carry out some engine trials in which Cornish boilers were used. Two tests were made at a London pumping station, at an interval of a year, with Cornish boilers, which, after all, are only Lancashire boilers with one flue. The boilers were not new ones, but were taken in the ordinary course of their daily work, and the tests were 24-hour tests, permitting accurate measurement. The boilers were worked to their full ordinary load, or rather beyond it. In both tests with these boilers an evaporation from and at 212° of 11·87 lbs. of water per lb. of coal was obtained—an extremely high result. Those boilers were only half boilers, as reckoned in the paper; they were boilers without economisers or feed heaters. In passing, I should like to say, with regard to the Babcock boiler, that I believe it to be a most excellent boiler, and I have not one word to say against it; it is as good a boiler as is made, though its evaporative efficiency is not greater than that of the Lancashire boiler. It may be a better boiler for central electric stations. As to that I am not giving an opinion, but only objecting to the statement that the Lancashire boiler has a low evaporative efficiency. Mr. Crompton states that the Babcock boiler will stand forcing, but he has not given us a single fact by which we can judge whether a Babcock boiler will bear forcing or not. He says that a boiler of a certain nominal power can be worked at 50 per cent. above its nominal rate. But one wants to knows what its evaporation was per square foot of its heating surface. I have rather a suspicion that the evaporation per square foot of heating surface was probably moderate.

Professor Unwin.

The third point is this: There is a comparison drawn between the short-stroke high-speed engines and what Mr. Crompton terms the long-stroke low-speed engines. He points out to us that Mr. Willans showed how very great the importance of high speed of rotation was in diminishing cylinder condensation. Mr. Crompton has so expressed himself in his paper that an impression is conveyed that high speed is the one special mode of controlling cylinder condensation, and it is not sufficiently put forward that there are three or four other methods. You may reduce cylinder condensation 20 per cent. by steam jackets; you may reduce it 20 per cent. by superheating; you may reduce it 20 per cent. by high speed of rotation; and you may reduce it 20 per cent. by expansion by stages; but, unfortunately, you cannot get 80 per cent. by adopting these methods together. It comes to be a question which of these methods is best in any particular case. As Mr. Robinson very fairly and frankly said at the last meeting, it is a fact that it is the long-stroke slow-speed engines which have, up to the present, given us the highest economy of steam.

The sum of the whole comes to this: I think Mr. Crompton in his paper has given us something like a formula for central station design. His formula is—Welsh coal, Babcock boilers, Willans engines, direct coupling. That is an excellent formula, but I do not think it is the only good formula. I have an impression that such formulas are, on the whole, extremely mischievous. Every case of a central station design has to be considered according to the circumstances of the locality, and various other things.

There is one other matter on which perhaps I can give information which will be new to some. Mr. Crompton has very rightly looked to superheating as a method which will in future have to be adopted in securing further economy in the working of steam engines. I object a little to the statement that it is to be a remedy for steam pipe condensation. I think that must be combated in other ways, because superheating has a far more important function. The true function of superheating is to control cylinder condensation, and not steam pipe condensation. It is stated in the paper that

Professor Unwin

in the days of low pressure steam superheating was an easy matter, but it is now widely different. Any superheating in these days is "very much in the nature of passing steam through pipes "at a temperature which amounts to nearly red heat, so that it is "little wonder that not many engineers have cared about tackling "such a difficult and risky problem." I think that statement is an exaggerated one.

There has been for 40 years in Alsace one of the best schools of steam engineering in the world. Superheating was first used in Alsace 40 years ago. Two years ago I had the opportunity of testing some engines in Alsace working with superheated steam. I suppose I am not exaggerating when I say that there are now in Alsace many hundred engines working at pressures up to 100 or 120 lbs. per square inch, and which are using superheated steam. The engine which I tested was a large compound engine giving 500 I.H.P. It was a modern engine, constructed six years ago, with a kind of Corliss gear, and separate admission and exhaust valves, and steam jackets—as good a compound engine as, I suppose, could be easily found. The engine was run for three days—two days with superheating, and one day without—and there was an economy of 20 per cent. of coal and 20 per cent. of steam when the superheated steam was used. The steam left the superheaters at 570° Fah., and entered the steam chest of the engine at a temperature of 520°. The engine had been working with that superheated steam for two years without the cylinder covers having been taken off. The fact is, there are difficulties about using superheated steam in modern days. But some of the difficulties which are put forward are not difficulties at all, and some of the difficulties which really exist are not sufficiently appreciated. The one difficulty which is always put forward is that with steam of this high temperature you will destroy your cylinders. Now I believe that is an absolute bugbear. In this engine, with the steam entering the steam chest at 520° Fah., there was no superheating inside the cylinder; the whole of the superheat was expended in diminishing the initial condensation. The dryness fraction of the steam at cut-off in that engine was about 0·65 when working without superheated steam, and about 0·85 when working with superheated steam.

Professor Unwin.

I admit that in Alsace the circumstances are rather favourable for using superheaters. They use very largely elephant boilers. They simply dig a pit underneath the boiler, and, without otherwise disturbing it, put the superheater down below the boiler. Apparently, with the conditions under which they work, they have exceedingly little difficulty, and I went through a great many mills where superheated steam was used. The stokers paid absolutely no attention at all to the superheaters; they do not know whether they are on or off. In the old days, when superheating was introduced, and when it always gave a considerable increase of efficiency, I think they made two very serious mistakes. First, they invariably placed the superheater in the coldest part of the boiler flues: they put it in the up-take or in some part where the gases had left the boiler. Second, as a consequence, they made the superheater large, cumbrous, and unsafe. If you have steam at a high temperature, and are then going to superheat it, it is no use putting your superheater in the coldest part of your flues: you have not temperature enough there to do the work. If you are going to use the superheater effectively, you must put it in some part of the boiler where the gases have a high temperature. In Alsace they put the superheater immediately behind the bridge. If you put the superheater in the cold part of the flues you must have an enormously large, and therefore dangerous, one; if you put it immediately behind the bridge you may have a small and safe superheater. Then a superheater must be so made that it will stand all the chances of daily work. If it is to stand all the chances of daily work, it must sometimes, no doubt, approach a temperature of red heat. I am not sure, but I almost think that that excludes from use a thin, ductile material like mild steel. At any rate, a superheater must be so constructed that it is practically a solid piece of metal without joints. Unless you can get that, I do not think a superheater will remain tight or permanently safe. The problem for our boilers and for our conditions has still to be worked out. It may be necessary, to meet our conditions, to adopt a detached superheater with a separate furnace. It is very encouraging to think that the superheater is so

Professor Unwin. largely used. Wherever it has been used in Alsace, it has given economies ranging from 10 to 20 per cent., and that not in bad engines, but in new compound, jacketed, and well-arranged engines. I think the fact that that is so is encouraging.

Mr. Peache. Mr. J. C. PEACHE: Among the boilers mentioned is the "Economic" boiler—a type of boiler which Mr. Paxman has been making for rather over 30 years. Mr. Crompton has mentioned a great many of the good points of this boiler; but there is one recent improvement that Mr. Paxman has made which I should like to point out. The diagrams on the screen represent four views of the "Economic" boiler. The lower diagram on the right-hand corner of the screen shows a section in plan. From that it will be seen that the tubes are divided into two groups. These two groups are close together at the back end of the boiler, and are separated at the front end of the boiler; there being sufficient space to enable a man to get in between them at the front end, and between the tubes and shell of the boiler at the back end. This arrangement leaves the boiler entirely open to internal examination—an advantage which is not shared by the locomotive, marine, or ordinary semi-marine types of boiler. One other feature which is of great importance in the "Economic" boiler is the combustion chamber. The fire-bricks with which this chamber is lined are brought to a high temperature, and form a very efficient means of consuming the otherwise unconsumed products of the furnace, and also of enabling bituminous coal to be used without trouble from smoke.

Table No. III. of Mr. Crompton's paper gives a list of boiler performances. This table, I think, the author intends chiefly as a basis of comparison for the use of engineers in charge of central stations—that is, for them to compare the results shown in that table with the results they have been able to obtain with their own boilers—and for that purpose of course it is a very valuable table; but for the comparison of different types of boilers it is of less value, because, besides the efficiency of the boiler, the efficiency of the stoker and the conditions under which the particular station is working also largely affect the results. Therefore this table must hardly be taken as a comparison between the efficiencies of the boilers referred to.

Table No. IV. gives what is called the maximum efficiency Mr. Peache. of sundry types of boilers at test trials. The last item but one, named as semi-marine type, and in which the evaporation from and at 212° is given as 12·2 lbs., refers to a trial of a Paxman "Economic" boiler, and is a fair average example of the efficiency of that boiler.

In the trials recorded in Tables III. and IV. no determination of the quantity of water carried over as water with the steam has been made; and therefore to a certain extent the figures given for evaporation must be open to question.

In the selection of a boiler one very important point is the cost of maintenance and repairs. There is only one instance given in the paper—that of the Kensington and Knightsbridge station—in the last four years' working of which that item is stated to have amounted to 5¼ per cent. per annum on the first cost of the boilers. That seems, on the face of it, rather a high figure for cost of maintenance and repairs. I am sorry I have not been able to get any figures from stations where the "Economic" boiler has been employed, so as to compare them. The figures have not been kept separate, and I cannot give them. I can only say, therefore, that Mr. Paxman's experience with the "Economic" boiler has proved to him that the cost for maintenance and repairs of this boiler, working under similar circumstances to those at Kensington and Knightsbridge, is very much less than 5¼ per cent. per annum on their first cost.

Professor A. B. W. KENNEDY: In view of the exigencies of Professor Kennedy time, I will at once proceed to make such addition as I can to the most interesting mass of information which Mr. Crompton has given us, and will omit the compliments I should otherwise have paid him. I will take the matter of coal first. In reference to Mr. de Segundo's remarks, I am pleased to say that my friend Mr. Grimshaw, at Eccleston Place station, has already got down to 4¼ lbs. per unit generated as the average for three months this year. I am sure, therefore, that this is very far from being an ideal result; we must all go much lower. I think, however, that Mr. Crompton has perhaps put the ideal a little too far down the scale. To get a somewhat more possible ideal,

Professor Kennedy.

we may take it that in the actual working time we can evaporate 10½ lbs. of water, under standard conditions, per lb. of coal, or, say, 10 lbs. of water actually turned into steam. If we take our stand-by coal at 8 per cent. (which is probable), and want, I regret to say, something like 3 per cent. for our pumps, and 5 per cent. for the steam pipe condensation, &c. (which in a big station we must have), we get down to 8½ lbs. of steam actually reaching the engines per lb. of coal burnt. Working that out on the basis (which, of course, is a very good one indeed) of 16 lbs. of water per I.H.P., and for a 77 per cent. efficiency between the dynamo and the engine at three-quarter load (which also is a very high figure), and taking 90 per cent. of the units generated as being actually sold (which, again, is an exceptionally high percentage), we get down to 3·64 lbs. of coal per unit sold, or about 3¼ lbs. per unit generated, as a really more or less attainable ideal in a condensing station. I hope the next time Mr. Crompton gives us a paper he may be able to tell us that he can give two or three examples in which this has been already obtained, and that therefore he was quite right, in 1894, in taking the possible standard as being considerably lower!

Professor Unwin has already dealt with the question of the value of North country coal. I so far disagree with him as to believe that it is more difficult to get the value out of North country than out of Welsh coal; although certainly, with proper care, the real proportionate value can be obtained.

As to boilers of the marine and semi-marine type, it may interest the members, perhaps, if I mention that in Glasgow, where nothing whatever but the marine type of boiler pure and simple is believed in, I have used that type on a large scale. One was naturally anxious to work with the cheapest fuel that could be obtained, and we have from the first used nothing but a kind of very inferior gaswork coke, known as "char," costing 4s. 6d. a ton, and certainly not worth more. It has been found, however, that this can be worked perfectly well in marine boilers if thick fires are used, and if the fires are not stirred up too much, without any adventitious aids in the shape of steam jets or mechanical stokers. The result is very favourable in cost. I

Professor Kennedy.

ought to say that the calorific value of the Glasgow coke which Mr. Crompton has given should be marked as approximate only, because, although I gave it to him as representing an analysis of the Glasgow coke, it was not an analysis taken at the particular time of my experiments.

I will not add more than a word to what Professor Unwin has said about Lancashire boilers. I have not myself obtained any such conclusive results as those which he has brought before us. I had, however, one particular trial—lasting, I think, 10 hours—made on a plant of Messrs. Easton & Anderson at Addington Waterworks, and published in 1890. We did actually obtain, at a particularly careful trial, an evaporation of 11·7 lbs. of water per lb. of carbon-value without economisers, and 12·4 lbs. with economisers. It should be noted, however, that, although the result was during actual working in ordinary fashion, the rate of combustion was very slow, being only about 6 lbs. of coal per square foot of grate per hour. I believe that such boilers can be made as economical as any other type if they receive the treatment which they ought to receive, which, of course, is not the kind of treatment which would be given to boilers of other types.

Mr. Crompton has stated in one part of his paper that certain figures are "unknown to the works engineers themselves." I hope I may be excused for once more laying stress on this matter. I seriously believe that the economy of a station depends very largely upon how far the engineers really measure what is going on in it. I wish this point could be taken to heart by the many men who are careless in these matters; I am sure they would find it would pay them, not to put it upon any higher ground, to set to work at once and measure everything they are doing, which can be now done with quite reasonable accuracy, no matter what the system of distribution may be.

The question of rope driving is one which comes next. I think it may perhaps interest the members to know that there are being conducted just now in Belgium, under the auspices of a large committee of Belgian engineers, a series of what I hope will be exhaustive and complete trials on this particular matter. Plant has been set up for the particular

Professor Kennedy

purpose of measuring the amount of power taken up by belts and by ropes apart from the power actually taken to drive an engine and do its work. At present I believe no figures on these questions are accessible to most of us; at any rate, I have found the greatest difficulty in getting any such figures which could be trusted. Of course, it is impossible to compare the efficiency of one dynamo driven by a rope and another dynamo driven direct, because there are so many other questions coming in besides the method of driving that the two cannot be compared. I hope when these results are published, as they are going to be, that we shall all of us be a great deal wiser for them.

Mr. Crompton has referred to a method for getting an accurate determination of the engine load-factor of each day. I think this is in the power of all of us with extremely little measurement. If the output of each engine is metered, and if the number of hours which that engine is run is also noted, you have really with sufficient accuracy for all practical purposes the load-factor of the engine per day. In my own practice I have these matters regularly logged, week in and week out, so that we always know the actual working load-factor, using this expression in what I believe to be its most important signification.

Then there are the "obscure losses" with which, I am sorry to say, my own name has been connected. I am glad to be able to give you some measurements connected with them which my friend Mr. Newington, at Millbank Street station, has made for me. All the condensed water out of the steam pipes, engine separators, and every other possible source of drainage waste, was run into a sump and pumped out into a weighed tank. It was found on several days to amount to from 8 to 9 per cent. of the whole weight of the feed water. In another station I have found it to be from 5 to a little over 6 per cent. Of course it would not be such a high proportion in winter when the load was higher; but it may be a very serious matter indeed, and this will be found by anybody who takes the trouble to measure it.

The question of condensation arises in the paper. I hope that I do not understand Mr. Crompton to mean that he really doubts whether there is any economy due to condensation. One paragraph in his paper almost reads as if he did.

Professor Kennedy.

I now côme to the last point of all—the matter of wages and superintendence in works. With regard to that, I should like to say that I think there is a little misunderstanding sometimes as to the effect of the size of the works on the cost of energy. The actual outlay in coal, stores, water, and repairs depends, not on the size of the station at all, but on the relation between its output, shape of load diagram, and size of units. The wages and salaries, on the other hand, taken per unit, are more or less dependent on the size of the station, and decrease as the station grows larger. In the first-mentioned section of expenses there are very often indeed cases in which a small station has a great advantage over a large one. Even in superintendence it often has advantages. Taking both sections of cost together, although it cannot be said that the cost in a station producing 500,000 units per annum must necessarily be less than in one producing 250,000 units (in my own experience I could easily give examples to the contrary), yet it may be said that at one and the same station the cost per unit will be greatly diminished if the output is increased from 250,000 to 500,000 units per annum. It is a matter of great interest to know at what absolute size of station the cost per unit would not be diminished sensibly by increased output. I think that when we come up to about 3,000 H.P., or possibly 4,000 H.P., at one station, we have probably reached a point beyond which practically no further economy in cost per unit will be obtained by mere increase of output. I said this, I remember, in a recent discussion on Mr. Ellington's paper at the Institution of Civil Engineers. He put the figures at a somewhat lower figure—I think about 2,000 H.P.—in connection with hydraulic power. Above 3,000 or 4,000 H.P. I believe that it will be found that the actual cost will be very much the same, whether the power be put into one or two stations. Whether one or two are used will then depend upon other considerations; it may, of course, be much more *convenient* to have one, but it will not, *per se*, make any great reduction, I think, in the cost per unit.

I am very glad to read the last sentence of Mr. Crompton's paper. He is one of those men who do an enormous amount of

Professor Kennedy. work, both personally and through assistants; and of all men in our profession he is one of those who is always most ready to give his assistants all the credit they deserve in the most cordial manner.

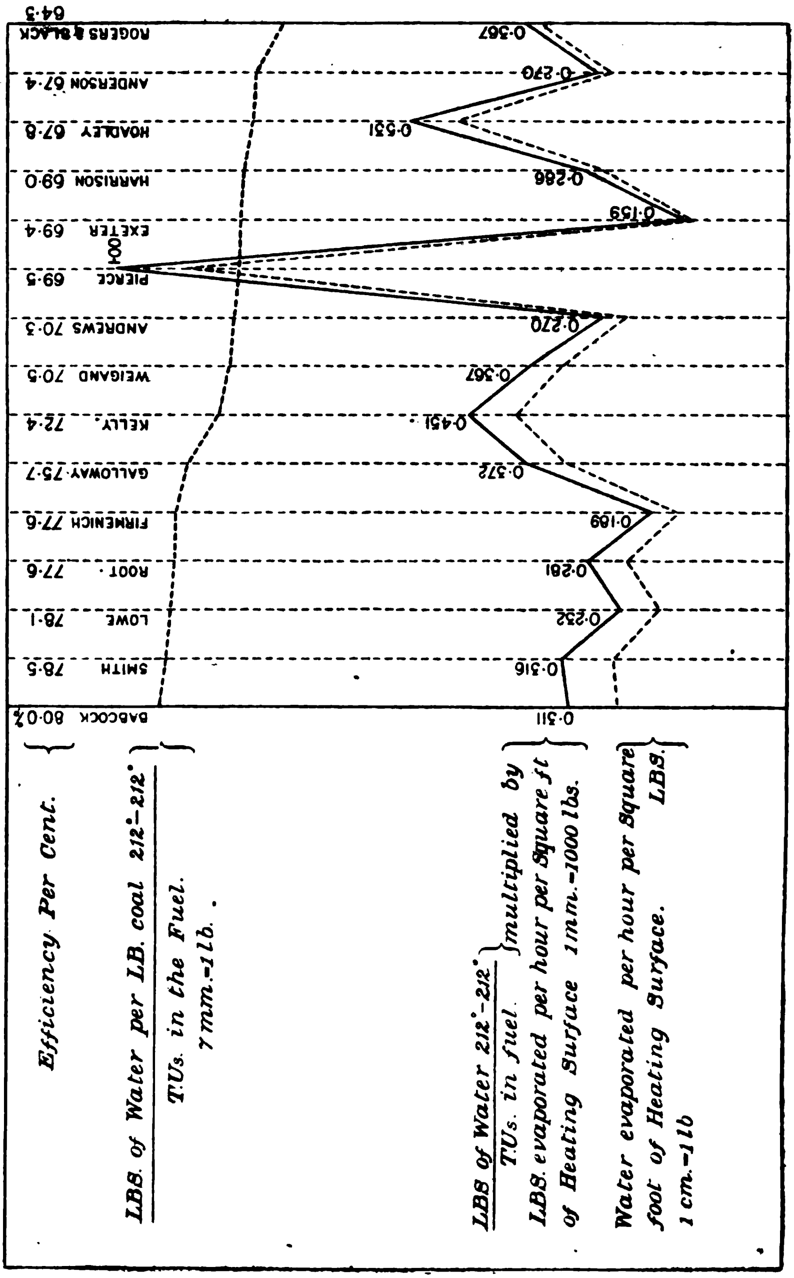
Mr. E. C. DE SEGUNDO: May I explain, in connection with Professor Kennedy's opening remarks, that my estimate of 4 lbs. to 4¼ lbs. of coal was per Board of Trade unit paid for by the consumers through their meters? The corresponding figure per unit generated would be about 3·7 lbs.

Mr. Halpin. Mr. DRUITT HALPIN: The first point I would wish to remark on is one made by Mr. Crompton in his paper, where he says he considers that small dust fuel is only less valuable because it is liable to fall through the bars. We are all aware of the mechanical disadvantage of using fuel under those conditions; but I think one very great source of loss in the fuel in this condition is often overlooked, and it appeals very strongly to those who have had to do with fuel stored in the tropics. When fuel gets disintegrated, it gets oxidised, and very much less valuable. I think it is on record that disintegration alone cannot so completely reduce its value. Amongst the highest thermo-dynamic effects ever attained were those produced by the late Mr. Crampton, where the fuel was perfectly pulverised. That fuel was used immediately after it was powdered, and no time had elapsed to allow oxidisation to take place. Mr. Crompton says that the locomotive boiler is not efficient on account of the level of the fire-bars. It is very evident that it cannot be efficient; but engineers using the locomotive boiler for stationary purposes have, unfortunately, taken it, "lock, stock, and barrel," and adopted it exactly as used on locomotives. As a locomotive boiler is used on a locomotive engine there is no more efficient machine in existence. The man stands on the level of the door, shoots the coal down, gets all the corners properly covered, and the grate properly filled. I saw a couple of locomotive boilers the other day. The man was about my own size; he lifted the shovel like a rifle up to his shoulder, and shot its contents into the fire-box, and then looked into the fire-box to see what had happened. This defective arrangement is very easily got over. There are

the beautiful results obtained in 1872 at the Royal Agricultural Society's trials, which were hardly ever equalled before or since, that were got by Messrs. Clayton & Shuttleworth at Cardiff. What they did was to carry the front of the foundation ring along part of each side of the front of the fire-box; they then brought it up in a horse-shoe form in the centre, and got the fire-bars slightly below the furnace door; the part underneath the door they filled up with fire-tile, and they got a reasonable depth of 6 or 8 inches above the fire-bars, thus enabling the firing to be done with the greatest possible efficiency. I think if all locomotive boilers that were working stationary plant were treated in the same way, so that the man could easily see what he was doing when firing, very much more efficient results would be produced. Mr. Halpin.

With regard to the question of the Babcock boiler, the details given us are perfectly reliable. Mr. Rosenthal was good enough to give me a book of their boilers, and there is a curve in the book giving the results of the tests made in the Exhibition of 1876 at Philadelphia which I have put out here. The upper curve gives the lbs. of water evaporated per lb. of fuel from and at 212° Fah.; the middle curve shows the lbs. of water evaporated per hour per square foot of heating surface. This lower curve which they also give is a very valuable one, as it shows the rate at which the boiler is working. It is perfectly useless to tell me a man is earning a hundred or a thousand pounds—I am as wise as ever, unless they give me the unit of time in which he is doing it; and this corresponds to the actual rate at which these boilers are working. If we know a man is earning £100 in a certain limit of time, we know everything. And in the same way we can treat a boiler. If we find a boiler is evaporating 3 lbs. per hour per square foot and is doing evaporation at 10 or 11½, or anything you like, if we multiply these figures together we get a new curve, which gives us the rapidity of evaporation multiplied by the economy of evaporation. The upper curve shows that the Babcock was at the head of all its competitors as regards economy, but it takes a totally different place if we look at the total result shown by the lower curve.

Mr. Halpin.


ROGERS & BLACK 64·5
ANDERSON 67·4
HOADLEY 67·8
HARRISON 69·0
EXETER 69·4
PIERCE 69·5
ANDREWS 70·3
WEIGAND 70·5
KELLY 72·4
GALLOWAY 75·7
FIRMENICH 77·6
ROOT 77·6
LOWE 78·1
SMITH 78·5
BABCOCK 80·0%
0·367
0·270
0·531
0·286
0·159
100
0·270
0·367
0·451
0·372
0·169
0·281
0·232
0·316
0·311
Efficiency Per Cent.
LBS. of Water per LB. coal 212°–212° / T.Us. in the Fuel. 7 mm.–1 lb.
LBS of Water 212°–212° / T.Us. in fuel. multiplied by LBS. evaporated per hour per Square ft of Heating Surface 1 mm.–1000 lbs.
Water evaporated per hour per Square foot of Heating Surface. LBS. 1 cm.–1 lb

Taking the final results produced by the Rurce boiler as unity— Mr Halpin. that is to say, taking the quantity of water evaporated into the economy with which he did it—he produced a result which here becomes unity, and all the others are represented proportionately by this curve; so that we have not alone to look at the economy of evaporation, but also at rapidity.

You may pay far too much for a sovereign, and, as Professor Kennedy said, they got an economy of 11½ lbs. in a trial he made; but he told us the whole truth, for this result was attained at a rate of combustion of 6 lbs. per square foot per hour of fire grate. They were simply doing nothing in this case. Mr. Crompton also told us that one of these boilers was doing 50 per cent. more than its normal work without giving any trouble. All I say is, Thank you for nothing. This particular boiler was doing under 3 lbs., and then it does 50 per cent. more, which brings it almost to 4½ lbs. The author has referred to the Lancashire boiler. I will give you one or two figures in connection with that boiler. Some trials were made by the South Lancashire Coalowners' Association, presided over by Mr. Fletcher, some 25 years ago. They were accurately made with boilers 7 × 30, and ordinary North country coal. These are the results of the average of 60 trials: The boilers evaporated 7·1 lbs. per hour per square foot of heating surface. They were using coal with 11,670 units, and they were doing at that rate a thermal efficiency of 0·827, which is a very big figure. As a result of that we have 7·1 × 0·825. That gives us a figure of merit so far to remember of 5·871. Comparing that with the Babcock boiler, that boiler, at the trial referred to by the author, was evaporating 2·893 lbs. per square foot per hour. The efficiency of the evaporation, as given by Mr. Crompton, is 0·760. Multiplying those together, we get 2·245; that is to say, we get 58 as the figure of merit for one boiler, and 22 for the other. I must go one step further. Mr. Rosenthal was good enough to give me the prices of three of those boilers, and I find the Babcock boiler has a great advantage in the way of cost per square foot of heating surface over the Lancashire boiler. The average cost for three of their boilers

Mr. Halpin. was 6·21 shillings per square foot of heating surface. Messrs. Yates & Thom, of Blackburn, also kindly gave me the prices for five of their standard Lancashire boilers working to 150 lbs., which is the same pressure as for the tubular boilers. Their price is very much higher—8·74 shillings per square foot of heating surface. So that, if we divide the results of the efficiency we have obtained by the capital cost at which these figures were obtained, we get something like a final figure of efficiency for boilers. If we divide this unit of 58 by 8·74, we get a figure of merit of 6·7. If, on the other hand, we divide the results given by the Babcock boiler—the efficiency of 2·245 by 6·21—we get an efficiency of 3·6. So that the boilers stand, with regard to rapidity of work, or the quantity of work they turn out, the economy with which they will turn out that work, and the capital cost necessary to produce these results, very nearly in the ratio of 2 to 1. That is quite apart from all questions of Lancashire boilers being able to use dirty water and burn smoky coal, which possibly the tubular boiler people would hardly claim their boiler to be capable of doing. It must be borne in mind that the above results with the Lancashire boiler were obtained with what the author would probably call half a boiler—that is to say, a Lancashire boiler working without an economiser, and using a very ordinary quality of North country coal.

Mr. Longridge, the chief engineer of the Engine and Boiler Insurance Company of Manchester, made some tests of a Babcock boiler in 1890, using ordinary North country coal, containing 13,769 B.T.U. As the first tests were not considered satisfactory, the furnace was altered, and further tests undertaken, which gave an evaporation of 2·657 lbs. of water per hour per square foot of heating surface, with an evaporation of 8·09 lbs. of water from and at 212° Fah. per lb. of fuel, or a thermal efficiency of 59; and $59 \times 2{\cdot}657 = 1{,}560$, against the 2,245 obtained at St. Pancras when these boilers were using best Welsh fuel. If the price of this boiler was the same as of those given me by Mr. Rosenthal, we get 1,560 divided by 6·21 equal to 2·51, against 6·7 for the Lancashire boiler using a similar class of fuel, or a final ratio of merit 1 for the Babcock boiler, against 2·68 for the Lancashire boiler.

Mr. J. H. ROSENTHAL: The previous speaker has reminded me of the fact that the discussion on Mr. Crompton's paper might almost be called a question as to which is the best boiler for a central station. It seems to me that, as regards this interesting paper, the boiler has been more amply discussed than any other portion which goes to make up a central station. Mr. Rosenthal.

During the last three or four years a good many electrical engineers have thought that the best thing to do would be to put Lancashire boilers in central stations, particularly in places where coal is cheap in the North of England, and where the saving of space is of no consequence. I have not received, or been able to obtain, any very complete data as to the results that are obtained in those places with Lancashire boilers; but the average experience obtained in the North of England of the working of Lancashire in ordinary factories certainly goes to show that the result is not more evaporation, as a rule, than from 6 lbs. to 7 lbs. of water per lb. of coal. There are, as Professor Unwin has mentioned, trials on record of magnificent results obtained with Lancashire boilers, and particularly with Lancashire boilers with large economiser surface behind them, utilising the waste gases. But these results are no criterion whatever for the design of a central station, because, excepting in a very few instances, it would not be possible to put as large boiler surface down of the Lancashire type as would be required to work at such a rate as to ensure the efficiency that is held up as the possibility of efficiency obtainable with a Lancashire boiler. So that on the whole I think that when an engineer designing a central station looks into the question he will find that a much better boiler for his purpose is either a water-tube boiler or an ordinary tubular boiler. As to a comparison between those two, I should like to say a word presently. The question of safety has always to be considered, and the question of upkeep likewise.

It is a very doubtful thing as to whether a Lancashire boiler is, under any condition, a good boiler for a high working pressure. I am not prepared to say that it is impossible to construct a Lancashire boiler to work at high pressure; but I have certainly seen a good many Lancashire boilers that were put down to work at

Mr. Rosenthal.

high pressure which have had their pressure reduced after a few years' work and become useless. As to whether those engineers who have put down Lancashire boilers to work at high pressure will experience the same result or not, is a matter to be seen after they have been in use sufficiently long to be tried. As to the possibilities of such high efficiency being obtained as Mr. Crompton mentions, his figures are undoubtedly very high, and it becomes a question whether it will pay in the long run to go to such refinements as are necessary to obtain such high figures. At the Popp compressed air station in Paris, a H.P. was produced on a plant of Babcock boilers and quadruple-expansion engines with 500 grammes of coal, containing about 1,400 British thermal units—that is, about equivalent to 1·2 lbs. of English coal. Only a day or two ago I received particulars of a plant of Babcock boilers in Calcutta working in connection with a triple-expansion condensing engine of 2,000 H.P., where the results amounted to the production of 1 I.H.P. with 1¾ lbs. of Indian coal, which would be equivalent to 1·2 lbs. of Welsh coal. So that it seems we are not, at any rate, very far off the figures that Mr. Crompton mentions as a possibility. Now it is said sometimes that the Lancashire boiler is better than the water-tube boiler or the ordinary tubular boiler in respect of the prevention of smoke. I mention only the water-tube and the multitubular boiler together, because they are under the same conditions as far as the prevention of smoke is concerned. If you work a Lancashire boiler very lightly indeed with a class of bituminous coal which readily cokes, you can undoubtedly fire the boiler so as to produce very little smoke. But if you have a dozen Lancashire boilers it is quite another thing. On the whole, you may take it that the Babcock boiler or the ordinary tubular boiler, to burn bituminous coal smokelessly, requires mechanical firing. And this is equally necessary with the Lancashire boiler. Mr. Halpin has given us a number of figures with regard to the evaporation per square foot of a Babcock boiler compared with a Lancashire boiler. Now those who are acquainted with boiler construction know that for a given amount of work to be produced economically you require more surface in every kind of tubular boiler than you do in a

Mr. Rosenthal

boiler in which the heating surface is merely plate surface. I submit it does not matter to the electrical engineer what the surface of the boiler is, as long as he obtains a certain quantity of steam for a certain quantity of coal, and the total power he requires costs him the same amount of money —as it certainly would do, if he took the rate of the working of the Lancashire boiler to obtain the same efficiency as that of a tubular boiler. I wish to say that it makes no difference to him whether he gets more surface for his money in the one case than he does in the other; it is a question of the total production of steam for a certain amount of money, as long as you obtain the same efficiency.

With regard to burning oil, I certainly think that oil-fuel will be used to some extent for dealing with sudden loads in an electric lighting station. There is no difficulty whatever in applying oil to a boiler that is ordinarily burning coal, so that it can be used at a moment's notice; but there are certainly no such fancy results to be obtained with it as Mr. Henwood has claimed; and so far as that wonderful type of boiler which he has sketched is concerned, it is simply a Yarrow or Thorneycroft boiler, or similar to any of the types of light-weight water-tube boilers, with tubes connected in such a way that you cannot possibly clean them. [Mr. HENWOOD: You are altogether wrong.] The question of the dryness of steam is one often discussed. Ten years ago almost every engineer I met said, "Oh, a tubular "boiler gives wet steam." I hear this less frequently now. I do not know how many cases there are of tubular boilers giving wet steam, but I think there are very few. I certainly think, from careful observation, that on an average, working at the same rate, in the manner I explained a little while ago, the Lancashire boiler does not give as dry steam as the water-tube boiler: I am not speaking of water-tube boilers that are built for light weight, such as are used on torpedo boats, because the conditions under which they are constructed and under which they are worked are altogether different. As I said before, it seems to me that the question of boilers has been more largely discussed in Mr. Crompton's paper than any other point. The last case where I heard of a plant of boilers producing very wet

Mr. Rosenthal. steam was at Deptford. The matter was investigated, and it was found that the steam as it came from the boilers contained only three-tenths of 1 per cent. of moisture, and that the wetness was produced in the steam pipes. Badly designed steam pipes is, I think, the most prolific source of trouble with wet steam in engines that we have to deal with.

Mr. Holmes. Mr. A. BROMLEY HOLMES [*communicated*]: Mr. Crompton's useful and interesting paper will be studied with advantage by all engineers connected with electrical supply. In his prophetic estimate of the future selling price of electrical energy, which he fixes at 3d. per unit, Mr. Crompton omits to make any allowance for depreciation. The experience of those who have been engaged in manufacturing businesses shows that it is not sufficient merely to provide for the annual cost of repairs necessary to maintain the plant in first-class working order, but that mere lapse of time entails a depreciation in value, and the consequent necessity of setting aside a depreciation or renewal fund to provide for the expenditure from time to time necessary to keep the plant up to date.

In a paper read before the Liverpool Engineering Society a few months since, the writer estimated the cost of electricity to the consumer in the near future on a business selling two million units per annum at the following figures:—

	d.	
1. Works cost, including maintenance	1·5	per unit.
2. Management	0·5	,, ,,
3. Profit	1·5	,, ,,
Total	3·5	,, ,,

To which was added an allowance of 1½d. per unit for depreciation reserve.

Mr. Crompton's figures for the corresponding items are as follows:—

	d.	
1. Works cost and maintenance ...	0·9	per unit.
2. Management	0·42	,, ,,
3. Profit	1·68	,, ,,
Total	3·0	,, ,,

As the writer's figures were based on sales of two million, and Mr. Crompton's on five million units per annum, there is a very close correspondence between them. Mr. Holmes.

In Table III. Mr. Crompton gives, under item N, the evaporation obtained by Lancashire boilers in Liverpool at 5 lbs. of water for each pound of coal. Mr. Crompton adds a note of interrogation to the 5 lbs.; and to make his table accurate this note of interrogation should be replaced by 0·48, as the evaporation, averaged over a long period, has been 5·48 lbs. of water per lb. of high-class Lancashire slack.

Mr. Crompton is in error in supposing that in the Northern counties little or nothing is said if smoke is produced. In Liverpool (and no doubt also in Manchester and other towns) the Corporation inspectors keep a most vigilant watch on the chimneys; but a Lancashire boiler, if properly worked, produces very little smoke and causes no nuisance.

The writer cannot help thinking that Mr. Crompton's experience with Lancashire boilers at Chelmsford (item J in Table III.) has been unfortunate, and that further experiment may enable him to secure better results.

The results given in last column of Table VI. are comparatively valueless unless accompanied by some information as to the average loads at which the engines are worked. In the early days of a supply station the unit size of plant selected is usually too large for the working conditions of the station, but as the demand increases this disadvantage gradually disappears.

A direct-acting high-speed engine which at full load will produce one unit per hour at the dynamo terminals with 30 lbs. of steam, will require approximately double this amount of steam, and consequently of fuel, when working at one-third load. From this point of view, Table VI., though of great interest historically, requires further details (which have unfortunately been impossible to obtain) to make it of great practical value.

Mr. Crompton does valuable work in calling attention to the great waste of fuel arising from the use of small independent engines for pumps and similar purposes. In the Liverpool supply stations considerable economy has been effected by replacing the

Mr. Holmes. stoker engines by electro-motors, and it is under consideration to deal with the pumps in a similar way.

Mr. Crompton is to be congratulated on the extremely favourable rates of maintenance which he has attained, as set forth in Table VIII. Unless the capital value of the accumulators is taken at an unduly high figure, the annual maintenance rate of 3¼ per cent. is one of which he may be justly proud; it will be a matter of great interest to supply station engineers to learn in the future if this remarkably low rate of maintenance can be continued during the succeeding equal period of four years.

Mr. Crompton must have expended a great deal of time and trouble in collecting and arranging the valuable information contained in his paper, and deserves the gratitude of all interested in electrical supply for his generosity in publishing the results of his experience so fully and freely for their benefit.

Mr. Hunter Mr. W. D. HUNTER [*communicated*]: In a paper dealing with the cost of electrical energy to consumers, it appears to me that the method adopted by Mr. Crompton, in leaving out of consideration directors' fees, salaries, and expenses, does not show the true cost of production.

I do not think the cost of management is outside the province of engineers, but is just as much an item to be considered as the choice of the system used, and the skill of the designer, and the interest to be paid on the capital expended. To my mind, the right thing to do is to take the TOTAL cost of production, plus a reasonable rate of interest on the capital employed to produce the energy sold to consumers; and the argument in favour of this is that one company may produce energy at a very low cost, but such a result may only be obtained by a large capital expenditure.

With regard to Table VI., in which the comparison of fuel used by different companies is given, the figure opposite my company (viz., the Newcastle and District Electric Lighting Company, Ltd.) of 310 British thermal units used per watt-hour, is wrong; it ought to be 204, and this I pointed out to Mr. Crompton before the reading of his paper.

As the result of careful experiment at our works, I estimated the average production of steam over the year to be 5 lbs.

per lb. of coal used—*i.e.*, the calorific value of the fuel used by us in conjunction with our ordinary method of stoking was only half that of Welsh coal evolving 14,500 British thermal units. Mr. Hunter.

I may further say that in the case of my company, after the experience of the past year, it has been found false economy to use a common quality of coal, in spite of its low cost. The fact, however, remains that such coal was used, with the result shown by the figures following:—

Total coal used during the year was 4,698 tons.

Calorific value, 7,250 British thermal units.

Total units sold, 372,922.

$$\frac{4,698 \times 2,240 \times 7,250}{372,922,000} = 204.$$

Mr. T. P. Wilmshurst [*communicated*]: Mr. Crompton's interesting paper, as might be expected, resolves itself into a vindication of the supposed advantages of low tension over high tension, water-tube over Lancashire boilers, and direct over rope driving. Mr. Wilmshurst

It is open to doubt, however, whether any comparison can fairly be drawn between the working results of a station serving only a compact area, and one serving a scattered and perhaps thinly populated area. If any such comparison can be made, surely the distance from the works to the farthest lamps, or the relative areas supplied, should be taken into account; but this consideration has been omitted from the paper—and perhaps wisely.

Examination of the *Electrician* supplement of January 5th shows that at the stations mentioned in Table VI. the distance from the works to the farthest lamps is, with the high-tension works, on the average *more than three times* as great as that from the low-tension stations. Had the low-tension stations had to serve similar areas to those of their rivals, would not the relative efficiencies have been widely different?

Apropos of Lancashire boilers, Mr. Crompton remarks, "At "any rate, the electric works using Lancashire boilers have not "hitherto shown at all well in comparison with other types."

Published records, however, appear to prove the *exact opposite*.

Mr. Wilmshurst. The works using Lancashire boilers appear in the front rank for economy—notably Birmingham, Bradford, Liverpool, Brighton, Leeds, Newcastle, &c.; and the lowest works costs on record of 2·10d. are obtained in a station using these boilers!

Rope driving also comes in for its share, and perhaps more than its share, of condemnation.

Examination of the before-mentioned supplement shows that the majority of stations now at work use ropes or belts; indeed, excluding the London stations, where ground space is the all-important consideration, the preponderance in favour of ropes becomes still more marked. It is a curious commentary on Mr. Crompton's criticisms that in the stations now under construction, designed presumably on the accumulated experience of past years, rope driving, Lancashire boilers, and alternating currents are being used in overwhelming proportion.

Mr. Gray. Mr. WILLIAM E. GRAY [*communicated*]: Although I made no attempt to join in the verbal discussion of Mr. Crompton's paper, in view of the time allowed for this being necessarily limited, I wish to join with other members in thanking the author for the very valuable paper he has laid before us on a subject which is of great interest, and which, owing to the difficulties surrounding it, has hitherto been dealt with incompletely. The data given are of exceptional value; but I cannot agree with many of the deductions drawn from these by the author, and to such points of difference I shall confine my remarks.

In referring to fuel, the author appears to consider that Welsh coal is the best under all conditions. Although this may be so with regard to London, where smokeless combustion is an essential, in other towns, with proper boiler arrangements, other classes of coal can be used with advantage. With a view to obtaining the maximum of fuel economy in the Silvertown Telegraph Works, where over 40 boilers are in use, we have been engaged for a number of years in the systematic test of coal; and, although the results cannot be considered as comparative with results obtained under other conditions, still in themselves they are of value. The type of boiler used for these tests is the Lancashire, with Galloway tubes, and fitted with mechanica

automatic stokers; and the tests were uniformly carried out, Mr Gray. admitting to the boilers feed water at 60° Fah., and evaporating steam at 60 lbs. pressure, the length of test extending over at least 12 hours. The boilers were worked at their normal rate in all cases, and the tests of the various kinds of coal were carried out in the same boilers, to ascertain which coal was most suitable and economical for use with these boilers. No test was made on the percentage of water carried over by the steam, and the following results were obtained:—

Class of Fuel.	Lbs. of Water Evaporated per Lb. of Coal.	Cost of Fuel, in pence, per 100 Gals. Evaporated.
Midland coal, average quality ...	5½	7¾
Durham coal, average quality ...	7⅓	7
Welsh coal, small nuts	6¼	10

The cost of fuel does not include delivery in London, but is probably a fair average for most towns favourably situated for fuel transport, and naturally on the cost of transport would greatly depend the class of coal to be used. But the above goes to show that, even in London, an economy can be effected by using Durham coal, if such steps are taken as are necessary to prevent any inconvenience arising from its use.

In considering the type of boiler to be used, the author appears to have somewhat lightly treated the claims for consideration of the Lancashire boiler. Where rent is high, water good, and rapid steaming an important factor, the water-tube and locomotive type boiler present great advantages; but in many towns rent is not high, water is not good, and rapid steaming—due to disposition of plant—is not an absolute necessity: in such cases the Lancashire boiler can be used with advantage. It may be objected that the question whether the water is good or not should be considered apart from the boilers. Unfortunately, this cannot always be done, even if the size of

Mr. Gray. the plant and volume of water to be treated justifies the erection of a purifier, as we cannot always be certain that the water passing through will be purified completely. The use of a purifier will, we know, allow us to use water which would otherwise be useless, and no doubt aids us in making indifferent water serviceable; still, we cannot ask for perfection in the purifier, and must seek for a boiler which will deal economically with the water at our disposal, whether purified or not, according to circumstances. The amount of moisture in the steam, and cost of upkeep of the boilers, must also be taken into consideration where economy is sought.

The author refers to superheaters. The economical advantages of these, properly applied, is undoubted; but before deciding to adopt this system on the score of economy of steam consumption alone, would it not be well to consider the cost of upkeep? Even under the favourable conditions mentioned by Professor Unwin as obtaining in Alsace, I am assured that the cost of maintenance is an important factor, and that many of the engineers who have closely followed the experiments carried out there have decided to await further improvements before adopting this system.

Dealing with engines, Mr. Crompton is apparently prepared to pin his faith to the high-speed type, directly coupled to the dynamo. Although there is no doubt that, owing to the great abilities of the late Mr. Willans, much has been done to improve this type, slow-speed engine makers have not been idle; and, as mentioned by Mr. Crompton, Carels, Treves, Sulzer, and other makers can produce engines which will be difficult to improve upon from the point of view of economy of steam consumption. The objection to the large space demanded for these engines as compared with that required for the high-speed type is, after all, a question of rent plus cost of maintenance; and it remains to be proved, for the high-speed engine, whether it can compete favourably on these grounds. In referring to the cost of oil for engines, it is to be regretted that the author draws no distinction between vertical and horizontal slow-speed engines.

Attention is drawn to the classification of Table VI., and it is

inferred that the difference in cost per unit is due to the difference in mode of drive. If this were really so, it would go far to support the author's contention that direct drive is to be preferred to rope drive; but the table shows that the rope-driven plant is nearly invariably alternating-current, while the direct is continuous-current. I must leave to others to decide whether the comparison is a fair one between these two systems, and confine myself to saying that it certainly is not a fair comparison between the relative values of the two drives. This the author admits when he shows that the initial efficiency of the high-speed plant described is little greater than that obtained with a horizontal slow-speed engine with rope drive. What the comparative efficiency would be after, say, six years, he does not tell us. Whatever the disadvantages of a rope drive may be, it certainly has the advantage of being a flexible, instead of a rigid, connection between engine and dynamo. Mr. Gray.

Although the author gives us no comparative costs of maintenance for the engine and boiler he prefers, he at least gives us the cost of maintenance of his underground system in use by the Kensington and Knightsbridge Company, his results being based on the last four years' working; but, as he gives no cost for maintenance of continuously insulated cables underground, I am at a loss to understand how he arrives at the conclusion that his system is less costly. To fill his omission, I give the figures published in the report of the Metropolitan Electric Supply Company.

Mains, including cost of laying mains, £141,639 0s. 8d. Repairs, maintenance, and renewals of mains of all classes, including materials and laying the same, £26 15s. 8d.

The system here employed is high-tension where the strains that the dielectric is subjected to are greater than those borne by the mains of the Kensington and Knightsbridge Company. As part of the cables were laid over four years ago, the comparison is a fair one. The result—*i.e.*, a cost of maintenance of less than 1-50th per cent.—does not bear out Mr. Crompton's contention.

In conclusion, if the reading of Mr. Crompton's paper tends to

Mr. Gray. convince electrical engineers that no standard type of plant is possible, but that the plant must vary according to the conditions of work, which must be carefully considered before the machinery is selected, then, in addition to the value of the tables he gives, the author's paper will have done much to prevent the industry following in a groove from which it will be difficult to stir, and which may lead to utter failure in many cases.

Mr. Sharp. Mr. ARCHIBALD SHARP [*communicated*]: No reference has been made in the discussion to the cost of energy for electric traction, possibly on account of its relatively much smaller importance on this side of the Atlantic, as compared with the cost of energy for electric lighting.

At the generating station of an electric railway or tramway, the peaks of the load curve have bases of about one-quarter to one-half a minute, instead of two or three hours as in an electric light station. These peaks occur at small intervals, corresponding to the time of starting of the trains or cars. The maximum ordinate of the load curve may be twice the mean ordinate, in which case the engines—which must be of power equal to that denoted by the maximum ordinate—will be running most of the time at half load, with a corresponding low efficiency. If engines of power just equal to that denoted by the mean ordinate of the load curve could be used, in conjunction with storage of energy for the peaks of the load curve, the efficiency of the engines would be increased and the cost of the energy diminished.

A fly-wheel of quite reasonable dimensions can be designed to give the necessary store of mechanical energy. Let W be the weight of the rim in tons, V the linear velocity of the rim in feet per second: then the energy stored in the rim will be

$$\frac{W\,V^2}{2\,g} \text{ foot-tons, } = \frac{W\,V^2}{948{\cdot}8} \text{ H.P.-minutes.}$$

If a variation of speed of $2\frac{1}{2}$ per cent. above and below the mean speed be allowed, the energy available will be $\frac{W\,V^2}{94{\cdot}8}$ H.P.-minutes.

The greatest safe speed of rim of large cast-iron fly-wheels of the usual type seems to be about 75 feet per second, though there are cases in which a speed of 100 feet per second is reached. Taking

a mean speed of 75 feet per second, and a variation of $2\frac{1}{2}$ per cent. above and below the mean, to get 100 H.P.-minutes available, 168 tons would be required in the rim, which is prohibitive. Mr. Sharp.

I have designed a high-speed fly-wheel which can be safely run up to a speed of 300 feet per second. The distinctive features of its construction are illlustrated in Figs. 1 and 2.

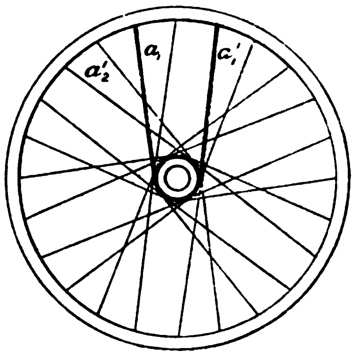


FIG. 1.

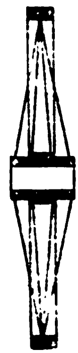


FIG. 2.

The nave of the wheel is suspended from the rim by a series of steel loops; one loop forming a pair of spokes is shown thickened. The ends of the pair of spokes are fastened to the rim by nuts. The portions of the spokes in contact with the nave lie in helical grooves cast on the latter. There is absolutely no fastening of the spokes to the nave beyond that due to friction.

The rim, being supported at small intervals by the numerous spokes, is nowhere subjected to large bending stresses due to centrifugal force, as is the case in large wheels with a small number of arms. It may therefore be run at a much higher velocity with safety. A wheel with mild steel rim and steel spokes may be safely run at 300 feet per second linear speed of rim. At this speed, and with $2\frac{1}{2}$ per cent. variation above and below the mean, $10\frac{1}{2}$ tons weight of rim would be required to get an *available* storage of 100 H.P.-minutes. Assuming that the form of the largest peak above the mean line is triangular, with a base half a minute long, the top of the peak would be 400 H.P. above the mean power required, and the fly-wheel would therefore be equivalent to an engine of 400 H.P.

Mr. Sharp. To get the above necessary high speed the fly-wheel would, in most cases, be fixed on the same shaft as the armature of the dynamo, a simple friction coupling affording a provision against damage by short-circuiting. The dynamo would still have to be of capacity equal to the *maximum* ordinate of the load curve, though the engine need only be of power equal to the *mean* ordinate.

The smaller the number of trains driven from the central station, the greater is the ratio of the maximum to the mean ordinate, and therefore the greater will be the saving effected by the use of such a fly-wheel accumulator. The saving is not only effected in first cost of engines, but also in working expenses; the steam consumption per I.H.P. being, as is well known, much less in an engine working full power than in the same engine working at half load.

Mr. Crompton. Mr. Crompton (in reply): The length of the discussion, the number of speakers, and the number of subjects touched upon, make it necessary for me to group these subjects, instead of replying to each speaker individually.

Several gentlemen ask why I selected works having such a large output as 5,000,000 units per annum as a basis for my ideal figures; and Mr. Hammond rather scared us when he said that the gross income of very few gas works would reach the sum of £62,000 a year, which is the gross income corresponding to 5,000,000 units at 3d. He, however, has now found out that he is mistaken in this, and that the income of a very large number of gas undertakings greatly exceeds this figure. At any rate, I have no doubt that, in London, the works of the Westminster Company, the Metropolitan Company, and probably the City of London Company, will reach this rate of output within two or three years; and that even the smaller companies with which I am personally connected will approach it so nearly that my ideal costs, so far as they depend on scale of output, may be also closely approached.

As to the capital cost of works capable of dealing with this output, I can assure General Webber, and Messrs. Geipel, Raworth, Hammond, and others, that I went very carefully into the existing figures before I satisfied myself that a works capital

cost of 2s. per unit sold was a correct figure to adopt. I arrived at this figure in the manner which General Webber himself would approve of—*i.e.*, I took the actual figures from the companies with which I am in close connection, and from these I prepared my calculations. I did not use the antiquated plan of calculating by lamps connected to the system, which, for many reasons, is no longer a useful guide. The two quantities, or factors, required are those which enable us to calculate the load-factor for any district, and can be easily ascertained from existing experience of works supplying electricity to a similar district; these two quantities are the maximum in kilowatts of load observed during the year, and the output in units sold per annum. The relation which this latter quantity bears to the observed maxima in various works enables us to say that the maximum rate of output, and hence the size of the plant, may be obtained by dividing the output per annum in units by a figure which is a number of hours, and which varies from 900 hours, or a load-factor of 10·3, in the case of some provincial towns, up to 1,300 hours, or a load-factor of 14·8, in my Kensington district, and to even higher figures in other parts of London. The quotient thus obtained is the maximum load in kilowatts. For the purposes of my paper I took the very safe figure of 1,000 hours, corresponding to a load-factor of 11·4, so that for an output of 5,000,000 units I require 5,000-kilowatt plant. In these works the generating plant must necessarily have from 20 to 25 per cent. of machinery in reserve, although the distributing plant need only be of the exact capacity, so that the 5,000-kilowatt load may be dealt with without undue fall of pressure in the mains. Mr. Crompton.

My capital expenditure of £500,000 is therefore a very safe estimate—in fact, I believe it to be an outside figure; but, much as I should like to enlarge on this point, space does not permit me to labour it. Messrs. Geipel and Hammond, and even General Webber himself, have, however, put figures before you showing that, in their opinion, it can be done at from £75 down to as low a figure as £60 per kilowatt; whereas it will be seen that I have adopted £100; and, as I am in a responsible position in regard to certain works designed by me, I know with reasonable

Mr. Crompton. certainty that the present plant in its completed state will, when working at present load-factors, not cost more than this sum—in fact, I hope it will cost considerably less.

The next point raised in the discussion was whether I am correct in asserting that the management and profit items in working costs are outside the province of us engineers. Messrs. Geipel, and Mr. Hunter, the engineer of the Newcastle and District Company, in his communicated remarks, have pointed out that these two items cannot be left out when considering the whole cost of production, and I agree with them; but why do they speak as if I had left them out? I think that the words in my paper, paragraph 2, page 397, sufficiently explain why I did not take up unnecessary time on this point; in fact, General Webber criticises me rather sharply for the little that I did say.

Coming now to my estimate of ideal costs, three speakers—General Webber, Messrs. Geipel and de Segundo—criticise me rather severely. Eight other speakers—among them Messrs. Raworth, Robinson, Kennedy, and Holmes—have, however, criticised them favourably, and taken these costs in the manner intended by me—viz., that my ideal costs were intentionally pitched high, and difficult of attainment. The fact that several of those who contributed to the discussion have already been able to show figures in some measure approaching to these ideals is a cheering one, and is the best answer to my first-named critics.

Mr. de Segundo has dealt with my ideal figures at length, but it will be more convenient to deal with his remarks, and those of others, on the subject of ideal boiler and engine efficiencies when dealing with these two matters further on; but Messrs. Hammond and Holmes offer serious matter for consideration on the depreciation question. On this question of depreciation opinions differ very widely, and I can only give my own as one among many; but I venture also to give my reasons for my opinion, which is sometimes said to be a dangerous course. I believe that in working costs there should be no allowance whatever for depreciation of plant. Of course, I am not dealing with the case of plant owned by local authorities,

Mr. Crompton.

who by the regulations of the Local Government Office are obliged to set aside certain annual sums as a sinking fund, so that at the end of a fixed period the whole capital that has been borrowed for the works will be paid off; but in the case of supply companies holding a concession for a limited term of years, I believe that the true course is to spend annually and charge against revenue such a sum as is sufficient to maintain the plant in perfect working order. During early years the annual sum required will be smaller than at a later date, when the plant has become worn; so that it is advisable during these early years to set aside a sum in excess of the sum actually spent on repairs, in order to equalise these maintenance costs from year to year; but if this has been properly done, at the end of the concession there should be no balance left over one way or the other—that is to say, the plant should be in perfect working order, and there should be no depreciation fund existing.

We are indebted to Mr. Hammond for inventing a highly useful word—"antiquation." This is an entirely different matter from depreciation, and I think no provision should be made for it. I do not think that other public companies, such as railway companies, water companies, or gas companies, ever have thought of providing an antiquation fund. What is the use of such a fund? I presume, to enable us in the future to purchase, and use for purposes of reducing working costs, any future inventions which we are now ignorant of; but surely, before the adoption of any such future improvement would be decided on, it must be shown to pay—that is to say, not only to reduce the working costs below their then level, but to such an extent as to pay the interest on the sum sunk on the improvement; and if it is of this nature, there could be no difficulty in raising fresh capital to introduce the improvement. Why should present rate-payers, or present shareholders, pay for improvements destined to benefit those who follow them?

Further than this, I cannot help feeling that this desire for an antiquation fund is due to an uneasy feeling in the minds of some engineers that their present plant is not quite what it should be —that it is already antiquated, and that they had better, as soon

Mr. Crompton. as possible, begin to set about replacing it by something better. I am happy to say that this is a feeling which has not oppressed me. When we already have such good generating plant as we have at present, and when our distribution losses are only 10 per cent., it is not easy for us to see what we are likely to gain from further improvements. Such improvements as are continually introduced into the best class of plant concern only the cheapening of the manufacture of that plant, and the future purchasers of it—that is to say, the plant in the future will be probably very little better than the present, but it may be very much cheaper; this, however, is no reason for antiquating present good plant in order to purchase cheaper plant of the same type and efficiency. It is for these reasons that I have left out depreciation and antiquation from my ideal costs, and only put in a sum of 0·4d. per unit, which I think will on the scale proposed be sufficient to keep the plant in perfect working order.

Value of Fuels.

As I had expected—I may say hoped—this important subject has been well discussed by those who are most competent to offer opinions on it. The discussion has only confirmed my views that the fortunate users of Welsh coal ought to congratulate themselves as having escaped the worries and uncertainties attending the use of the bituminous and other coals which contain so much of their thermal efficiency in the form of hydrogen. I see that Mr. Raworth and Professor Kennedy support me strongly on this point; and although Professor Unwin quotes tests to contradict my views, he only quotes test runs which, as I have shown by my Chelmsford experience, only lead to erroneous conclusions whereas those who support me do so from their knowledge of the continuous figures of the many works with which they are connected; but I think that the words Mr. Hunter, of the Newcastle and District Company, makes use of in his communication are most significative. Mr. Hunter, in wishing to reduce the figure which I give in Table VI. of 310 units per watt-hour sold, says that the calorific value of the Newcastle slack used by him is only one-half that of Welsh coal—that is to say, 7,250 British thermal

units—and on this basis he corrects or reduces my figure of 310 to 204 British thermal units. Now I thoroughly sympathise with Mr. Hunter in this. I know that, with ordinary boilers and ordinary care in stoking, the slack that he uses will only evaporate about half the water that he could evaporate with Welsh coal; but from my own experience at Chelmsford, where I have been using precisely similar coal to that he uses, I am convinced that if he has a calorimeter test made of his slack he will find that I under-estimated its value, and that it contains from 12,500 up to 14,000 British thermal units, a large proportion of these being in the hydrogen form, and thus extremely difficult to utilise; and he will also find out the truth of Mr. Halpin's remarks on the extent that this small slack deteriorates by exposure to the air. I do not think that Professor Unwin has any right to say that the use of Welsh coal is one of the factors of my formula. I pointed out, and I now re-affirm, that we in practice find out that it is easier to get a good result with Welsh than with the other coals. I never said that it was impossible, but only that it was difficult, to get good results with the other coals. Mr. Crompton.

We now come to the vexed question of flued *versus* tubular boilers. Some speakers will have it that it is Lancashire *versus* Babcock, but it is not so. Here my friendly critics are more numerous than the adverse ones. I fully expected to call a storm down on my head when I raised this question, but I raised it advisedly, after carefully watching and comparing the results in works using the two types, and after many and careful tests had been made by me personally. It is unnecessary for me to refer individually to the advocates of the Lancashire boiler. Their one cry is that in the past Lancashire boilers have given good results as steam raisers, and that on tests they have shown practically as good results as other types; but no advocate of these Lancashire boilers has attempted to explain why in the works E, N, O, and J the evaporation is so low. I have given my explanation. I have shown that, whereas at works J the results on test runs were 9 lbs. of water evaporated per lb. of fuel, the year's accounts show that only 5·2 lbs. were evaporated. I have traced

Mr. Crompton. this difference in results to the falling off in evaporative efficiency which always occurs when the Lancashire or Cornish type of boiler is irregularly fired, as it always must be when used in electrical works, and to the further difficulties which arise with this type of boiler if the coal varies even slightly in composition. I have shown that these differences can be reduced by the use of economisers—which virtually are a tubular addition or extension to the Lancashire boiler, making it partly a tubular boiler—and that these differences do not exist to the same extent when tubular boilers are used, whether of the Babcock type or of the internally fired type, such as the "Economic" or marine; and if all that has been said in the discussion is carefully read, it will be seen that no one has seriously controverted this view.

I object strongly to the statements made in the course of the discussion, and in the leading articles in the technical journals, that I hold a brief for the Babcock & Wilcox type of boiler. This is a cheap form of criticism, which happens to be exceedingly wide of the mark. Three years ago, when discussing the best type of boiler for electrical works, I thought that the internally fired boilers ought to beat the Babcock, or any externally fired type, on account of reduced losses during periods of banking the fires; therefore it was only simple justice on my part that I should state the results of my more recent experience during the last three years, when I find that, after fair trials of all types, the Babcock, which is an externally fired boiler, still holds its own.

Mr. Rosenthal has very fairly defended this type of boiler from the attacks made upon it during the discussion. So many well-qualified speakers have admitted that it is free from the defects of producing wet steam, and that it gives good evaporative results in supply works, that the only important point necessary to notice is how this class of boiler stands in regard to forced firing. I believe in this respect it is the best of all the boilers I have tried. I have, for the reasons given by Mr. Rosenthal, and which I consider to be very fair ones, never considered the question of heating surface in regard to this boiler, or, in fact, of any other boiler. The practical question which we engineers have to consider is not the one of heating

surface, but of the space occupied, and of the evaporative efficiency of a boiler which at certain times must give a certain output. When tested by this standard, I find that the method of preparing a figure of merit advocated by Mr. Halpin is not correct. His method is to obtain from the three factors of evaporative efficiency, pounds of water evaporated per square foot of heating surface, and cost of heating surface, a figure which he shows to be from two to two and a half times greater in the Lancashire boiler than in the Babcock. In reply to this, I have prepared during the last six years a very large number of estimates of boiler plant, and have most carefully considered the cost per thousand gallons per hour which can be evaporated at periods of maximum load—that is to say, when the fires of both types of boiler are being forced. I find that under such conditions, when all items of cost, exclusive of economisers, are added in in both cases, at this size the prices of the two types of boiler are practically identical, but that the evaporative efficiency when Welsh coals are used is in practice at least 25 per cent. in favour of the Babcock; and when we add to this that the Babcock boiler occupies just about half the floor space, and that it is far easier to deal with, there is little wonder that those who have had experience of both types exhibit the preference that I do. Still, as I have explained above, the question is not between Lancashire and Babcock, but between flued boilers generally and tubular or tubulous boilers; and I do not offer any strong opinion on the comparative merits of these two last-named types. I have had as good results from one type as the other, and no doubt the choice between the two will be determined in each case by special circumstances. How local circumstances affect design is very well shown by the remarks of Messrs. Burnett, and Peache, on behalf of Messrs. Paxman. Both gentlemen are makers of what I have called the semi-marine type, but which Messrs. Paxman call the "Economic," and Mr. Burnett the "Dry-Back" type. Mr. Paxman makes the boiler longer, and smaller in diameter, which suits the Welsh coals we find in the South of England; whereas Mr. Burnett, having to deal

Mr. Crompton.

Mr. Crompton

with Scotch coals, prefers a large-diameter short boiler; and both types are giving excellent results.

Mr. de Segundo has been at great pains to show that my ideal boiler efficiency is an impossible one, but his method of first deducting the principal source of boiler loss—*i.e.*, the heat units which go up the chimney—before he calculates the boiler efficiency, is very unusual, and differs from the system usually adopted. Of course, under such circumstances, when the one large source of loss has been eliminated, the boiler efficiency can show exceedingly high.

The figure of a possible 12 lbs. and a 10 lbs. working evaporation adopted by me is, I am convinced, not an impossible one, as so many authenticated tests show: among these, I will point not only to the trials made by Professor Robinson at St. Pancras with the Babcock & Wilcox, Professor Kennedy at Eccleston Place with an "Economic," and Professor Kennedy with a Thornycroft boiler, which in each case show an evaporation in excess of what I require, but to the well-authenticated trials made by the Royal Agricultural Society of England at Cardiff and Newcastle, and to the 60 extended trials quoted by Mr. Halpin with Lancashire boilers.

I note Mr. McLaren's preference for locomotive boilers, which is not to be wondered at, as he has obtained such high results in competitive trials when these boilers are used; but Mr. Halpin and Mr. Burnett have admitted that the type of locomotive boiler usually now built is a very awkward one to deal with in central stations; and, moreover, I think Mr. McLaren would not find that a locomotive boiler comes out well when required to be of the large sizes we generally require in supply works.

Mr. Geipel seems to think that the use of boiler fluid should be discouraged, and that it is an unworkmanlike method of dealing with the question of deposit; that where water is bad, special purifying plant should be used. Here, again, it is a question of special circumstances. There is no doubt that where the water is beyond a certain degree of hardness, purifying plant must be used; but there are many cases, such as that of the Thames water supplied by several of the London

companies, where the hardness is not sufficient to warrant the use of purifying plant, and where the use of small quantities of boiler fluid at the proper time will result in keeping the boiler absolutely free from any deposit whatever. It is not a question of allowing the deposit to form, but of keeping the boiler absolutely clean, and this can be done, and is done in practice in the best works. Mr. Crompton.

On the question of oil fuel Mr. Henwood is evidently an enthusiast, and I should be very pleased to see the rosy figures named by him realised in practice; I for one shall be well content if we get a much lower duty from the oil than that given by him. The great obstacle to the large introduction of oil fuel is the present price of the oil; and until this is considerably reduced, all our experiments must be in the nature of adopting oil for periods of forcing only. So far as experiments have gone, I believe that with the Babcock type the output of boilers under conditions of forcing will be nearly doubled; and I am glad to say that even under these circumstances this type of boiler still produces dry steam.

It is disappointing to see that the question of economisers has been so lightly touched on in the discussion. I had hoped to hear the experience of gentlemen who are large users of this class of plant, more particularly as to the cost of the upkeep of this extra item of plant. What we electrical engineers want to know is the cost of maintenance of economisers exposed to the very high pressures now prevalent.

On the subject of high- *versus* low-speed engines, it is very evident from the discussion that opinions have advanced very rapidly in the same direction as my own; and that, whereas, as I have stated, in my paper six years ago I was almost alone in advocating their use, now the great majority of speakers either admit that they are the most economical and convenient form to use in supply works, or they have arrived at the half-way stage of admitting that direct driving is of great importance.

I challenge the correctness of the remarks of Mr. Wilmshurst when he says that in the most modern stations rope driving, alternators, and Lancashire boilers have been, and are to be, used

Mr. Crompton.

in overwhelming numbers. On the contrary, there has been a distinct tendency in all recent specifications to do away with rope driving. A notable conversion to direct driving has been Mr. Raworth, and the only two speakers who still speak lovingly of the long-stroke horizontal engine are Professor Unwin and Mr. Gray. I think both these gentlemen have been influenced by their surroundings—that is to say, by the very beautiful steam plant of this type which has been manufactured of late years on the Continent. The eye of a mechanical engineer is taken by the design, workmanship, and high efficiency shown by the engines of Van der Kirkhove, Carels, and others; but even among these famed makers a feeling in favour of high-speed engines for electric supply works has already set in, Messrs. Van der Kirkhove being the first on the Continent to take up the manufacture of the Willans type of engines, and are now advocating its use for such works.

I have already taken objection to Professor Unwin having fathered on me a formula for the design of supply works plant. It may be true that the figures which I have collected for purposes of comparison show that certain supply works containing that class of plant have done better than others, but nothing could be further from my thoughts than to suggest a hard-and-fast formula to suit all cases. Professor Unwin says that in my paper I convey the idea that high speed of rotation is the one and only method available for reducing cylinder condensation, and that I have neglected the other methods—namely, use of jackets, superheating, and expansion by stages. With great deference to Professor Unwin's high standing and special knowledge on this subject, I must point out to him that here he is wrong—that high speed of rotation is not a method alternative to these other methods, but it can be superadded to all or any one of them; and that, in addition, high speed of rotation offers us great advantages by reducing the size, space occupied, weight, and hence the cost, of both the engines and dynamos, while at the some time it increases their economic efficiency; so that from all points of view it is the most satisfactory modification of design which the special requirements of electric lighting supply works have forced upon us.

Mr. Crompton.

As to my ideal figures of steam consumption, I have already said that these were intentionally pitched high, and difficult of attainment; but Mr. de Segundo's figures are evidently too much the other way. It is no use to compare them with mine, as he deals with non-condensing, whereas mine refer to condensing engines; so that his best possible figure of 4 lbs. of coal per unit sold with a non-condensing engine cannot be compared with my 2½ lbs. with a condensing engine; but even with non-condensing engines Mr. Barley, at Knightsbridge, and Professor Kennedy in more than one of his stations, have already reached a point below 5 lbs. in some of the winter months, and at Knightsbridge 3½ lbs. has been reached during test runs of considerable duration.

I have now to deal with the lengthy criticisms which have been made on Table VI. Several small errors have been pointed out, which I have duly corrected. These lie chiefly in the efficiency of distribution, and consequently alter the thermal units used per unit generated. General Webber is the only speaker who has impugned its accuracy as a whole, on the grounds that he is able to state from personal knowledge that the Chelsea Company, of which he is a director, refused to supply the imformation requisite to correct and supplement the published figures. It is true that this refusal caused an error in the distribution efficiency of the Chelsea Company, which I have already admitted, but it was the only refusal that I received. It did not cause me to draw any false conclusions, as I did not use the Chelsea figures in my averages, and I have based no arguments on them. It is, however, evident, as the order of merit in this table is based on column 4—that is, the B.T.U. per watt-hour sold—that the Chelsea Company, costing 1·11d., and using 142 B.T.U., occupies a figure of merit somewhat higher than that of the Charing Cross and below that of the St. James and Pall Mall Company, which is a high position, on which Mr. King and his staff are to be congratulated.

I hope Mr. McLean does not think I intended to throw doubt on the Oxford figures. On the contrary, when I said that they appeared almost too good to be true, I certainly intended to congratulate him on the splendid results obtained in such a short

Mr. Crompton. time after the starting of this station. I indeed consider them very encouraging to those who, like myself, think that the Oxford system is in many respects a more satisfactory method of dealing with the supply of scattered districts than the ordinary converted alternating system. Again, I thoroughly agree with this speaker as to the advantages of keeping records in very full detail; but he quite misunderstood my remarks on the distribution efficiency obtained at Chelmsford. I pointed out that, although the efficiency shown was high, it was not fair for us to take credit for it when compared with companies who supply throughout the 24 hours, as we gain considerably in efficiency from switching off the energy during a part of the daylight hours.

I am glad to find that Mr. Dykes has been able to so satisfactorily explain the Preston figures. At the time I worked out these figures for my table I felt sure that some such explanation would be forthcoming. His explanation shows clearly that a direct system, if used without accumulators, loses many of its economical advantages.

I value Mr. Holmes's remarks very highly indeed. He has had the longest experience of central station supply of any one of us, and has been so uniformly successful in his results that I am glad that his own calculations corroborate so closely my own ideal figures. He is, no doubt, right in attributing his rather heavy coal bill to the peculiar circumstances of last year's working, which, owing to the opening of new stations, led to light loading of his engines; but I still think that he has suffered more than he will admit from the difficulties I have dwelt on in my paper in efficiently burning slack coal in the Lancashire boilers.

I am afraid I cannot enter at any length on Mr. Wilmshurst's communicated criticism, further than to say that he is mistaken in thinking that Table VI. does not allow us to draw useful comparisons. Take the case of the works D, belonging to the House-to-House Company, on the one side, and compare their costs with those of works K, U, and W. All of these four works supply a residential district of the West End of London, and the conditions as regards compactness of supply are very similar throughout; yet we find that works D use fuel in the proportion

of 265 to works K 142, to works U 116, and to works W 84. Surely such great differences (which in these four cases have been taken very accurately indeed) are instructive as to the relative economical value of the systems used; and we may carry the comparison a step further, and point out that this is a case where the smaller first cost of the works D, on account of the reduced cost of their mains, ought to have led them to compare favourably from the point of view of dividend-paying with the other three works, whereas the working costs of D have been so high as not to permit of this. Mr. Crompton.

Again, Mr. Wilmshurst's conclusions as to Lancashire boilers are in direct contradiction of the data obtainable from Tables III. and VI.—so much so, that I cannot think he has ever studied these tables, or attempted to check their accuracy with the recorded figures that he mentions.

I am glad that Professor Kennedy and other speakers agree with me as to the great importance of studying and tabulating all the sources of loss which he has called "obscure works losses." These, which are common to all systems, have been very generally under-estimated, and hence have been neglected, and have gone on from year to year unchecked, and I hope that my paper may have done real service in calling attention to their importance.

Coming to the question of losses in the distribution, or efficiency of distribution, several speakers have raised this point, and the admirers of the converted alternating system of distribution have been anxious to show that the heavy losses in the first group of Table VI. are exceptional, and that the 82 per cent. efficiency of the City of London Company is what we are to expect in the future from improved converted alternating supply. I hope this may be so, but I am convinced that up to the present time the average distribution efficiency of 66 per cent. shown on Table VI. has been the rule and not the exception; and it remains to be seen whether the attempts to better this figure by employing extra plant and staff to switch transformers in and out of circuit, may not result in such an increase in the wages of staff as will counterbalance the gain in efficiency,—and this will be especially the case in smaller works serving scattered suburban districts.

Mr. Crompton. I take this opportunity of saying that my own personal conversion to the advantages of alternating distribution, which Messrs. Raworth, Geipel, and others so obligingly state has already taken place, must be deferred until I have had better evidence than exists at present as to the possibilities of reducing the working costs of the alternating system. This evidence is not yet forthcoming. The accounts of the two companies at Newcastle, Bournemouth, the House-to-House Company, and even the City of London, are very, very far from showing any such marked improvement as might lead me to be so converted to the converted alternating system, or to ignore the converting losses.

The published accounts of Continental and American supply works, and the reports and conclusions based on these accounts by Continental engineers, show that the majority of these gentlemen hold opinions very similar to my own, but I specially refrained from dragging the question into the discussion. This weighty question can now only be settled by results. Time will show who is right, and it is only wasting the time of this Institution to prolong arguments on a matter like this, which at present can be only one of opinion. It is for this reason that I did not mention in my paper the question of saving by use of accumulators; although the above-mentioned Continental engineers have quite recently shown that the best results on the Continent, as in England, have been obtained from stations where accumulators are used to a judicious extent. At the same time, I thank Mr. Shoolbred for showing this so clearly in the case of the Bradford works.

Similarly, on the question of maintenance, Mr. Gray has raised a very interesting question, which, however, deserves a paper entirely to itself—that is, the comparative maintenance cost of different systems of underground conductors. The subject is far too important, and involves such large issues that I only touched upon it as far as to give you our own actual figures for the Kensington and Knightsbridge Company. Mr. Gray, however, quotes figures to show that the continuously insulated cables belonging to the Metropolitan Company cost even less

for maintenance than the system of the Kensington and Knightsbridge Company, which is three-quarters of it bare copper in culverts. Although I willingly testify to the extremely high quality of Mr. Gray's cables, yet I do not think that the case he brings forward is a fair one to quote, as the peculiar system adopted by the Metropolitan Company, and which is not likely to be repeated elsewhere, happens to be one which does not expose these continuously insulated conductors to the peculiar source of wear or decay which is generally found. I allude to the point of weakness which occurs at the points where the insulation of the cable is cut into to form a T joint for the attachment of a customer to the mains. A company such as the Kensington and Knightsbridge Company has at present about 2,000 such T joints on its system; and we find that, whereas all T joints of continuously insulated cables require some attention and give some trouble, the same T joints on bare copper give no trouble whatever; and I should mention that the major portion of the cost of upkeep of the Kensington and Knightsbridge system as given by me in my paper is expended on the maintenance of the T joints of the continuously insulated portion of that system. Mr. Crompton.

I hope Mr. Schönheyder will understand that I had no intention of adversely criticising his water meter, which I use so largely in boiler trials, when I said that it is advisable to frequently recalibrate it; the reason is that, although Mr. Schönheyder's meter is one of the best I know, yet, as in order to eliminate errors due to leakage as much as possible the meters used on these trials must be placed at a point on the line of pipes as near the boiler as possible, it has therefore to pass hot water through it, so that there is a constant liability of cutting and friction from gritty deposit.

I have to thank Mr. Hammond for his appreciation of the objects of my paper; he has himself done good service in the preparation and publishing of statistics, so that he is in a position to sympathise with anyone who, like myself, has to face the difficulties of getting data together. But I am glad to say that in some works the data are already in such good order that it was

Mr. Crompton. an easy task to obtain what I wanted from them; in other cases it was far more difficult; and yet it was quite impossible to take a bird's-eye view of the situation, so that I could get on with the paper, until I had got the figures for the Tables III., VI., and VII. in a rough form. This task, simple as it now seems, was a work entailing much labour and correspondence. Although a few errors may still exist in these tables, no one has brought forward evidence to show that these exist to a sufficient extent to detract from their value as a means of comparing the present economic efficiency of the electrical works that were in operation at the commencement of this year.

The President. The PRESIDENT: After the marked expression of your appreciation of Mr. Crompton's very interesting and valuable paper, it seems unnecessary to ask from you a formal vote of thanks to him. But I desire to express my personal regret at having been unable to be present either when the paper was read or at the last meeting, when the discussion upon it was commenced.

I have to inform you that Mr. H. D. Wilkinson, Member, who was the engineer in charge of the British section of the Machinery, Mining, and Electrical Department at the Chicago Exhibition last year, has written a paper entitled "Notes on the "Electrical Tramway System of the United States and Canada," which it was the intention of the Council should be read this session; but the interesting discussion on Mr. Crompton's paper has precluded this; and it has been arranged, therefore, to have Mr. Wilkinson's paper printed in the *Journal*, and he will read early next session a short supplementary communication, which will be discussed together with the original paper.

I have to announce that the following candidates have been duly elected:—

Foreign Member:

W. P. S. Jansen.

Member:

Nathaniel Shepard Keith.

Associates:

Arthur Barrett.
Ellis H. Crapper.
C. Howard Doughty.
Walter Eccles.
Herbert F. Foster.
Charles J. Garnett.
George A. Goodwin.
Thomas Harden.
Percy Huddleston.
G. C. F. Székács.
Herbert Alfred A. Wood.

Students:

Percy Rhodes Cobb.
Alfred Howard Gossage.
Albert E. Makovski.
Arthur Oliphant.
Alfred Lovell Phillips.
Basil J. Ross.
Charles Stirling.
Howard Stanley West.
Leopold A. S. Wood.

The meeting then adjourned.

NOTES ON ELECTRIC TRAMWAYS IN THE UNITED STATES AND CANADA.

By H. D. WILKINSON, Member.*

Mr. Wilkinson. During the period of the Chicago Exposition last year I had opportunities of looking into systems of street traction in that city, and of discussing points of immediate interest with engineers from different cities whom it was my privilege to meet.

For several weeks previous to the opening of the Exposition the scene for miles round was one of the greatest activity in the construction of street tramways, centring from all districts on the south side, and forming connections from the city main cable car lines. The continuation of the elevated steam road to the Exposition along Sixty-fourth Street was also a smart piece of work, including the erection of six stations and a pin-connected truss bridge across the Illinois Central Railroad track without obstructing traffic. Immediately this line was finished trolley wires were strung underneath the girders, and the previous horse car lines, which had grown totally inadequate to the traffic, were converted into electric lines. The motor cars were rarely without trailers, and in the busiest times of the day two, and sometimes three, fully loaded passenger cars were hauled. The term "fully loaded," when applied to cars in America, must be understood in its most literal sense. Besides all standing and sitting room being taken up inside, the drivers' and conductors' platforms are closely packed, and people cling to the outsides wherever there is the smallest foothold. More than this, I have seen cars on busy days with people sitting on the window ledges and climbing on the roof, and the back end of the car framework weighted out of shape and scraping the ground. After seeing one motor car hauling two or three trailers, with 250 people, at the rate of 10 miles an hour, on roads with no drainage and covered with mud, I was convinced that the practice of putting

* This paper will be discussed at one of the first meetings after the recess.

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two 25- or 30-horse motors on one car—which would otherwise seem a waste of material and power—was not unreasonable. The full power is, of course, not always wanted, and can be regulated by the controller to suit the traffic; but it is most important to have motors that will stand extra heavy work when required and need no attention. During the year the number of passengers on all lines in Chicago was about 288 millions, or an increase of 55 millions over the previous year.

The general type of construction in wide thoroughfares is with poles planted in the centre of the road between the double track, carrying iron brackets for the support of trolley and feeder wires, and the general appearance is far from unsightly. This is specially the case when every other post supports an arc lamp or cluster of incandescents and the brackets are ornamental. Span wires are only necessary at curves and in narrow thoroughfares. The entire track construction, including rails and wires, costs about £1,400 per mile, and the car bodies, with motor trucks complete, cost about £800 per car. For a line, say, of 5 miles of track, with 15 cars, the power station, including building and machinery, would cost about £5,000, and real estate and car barns about £3,000,—bringing the total cost of equipment to £27,000. The revenue per car mile was from 20 to 30 cents, and the total running expenses 14 to 16 cents, or on the average about 60 per cent. of revenue.

The very energetic body of the American Street Railway Association is thoroughly representative, and its members, who are all engaged in tramway work, think nothing of travelling 1,000 miles to be present at their annual conventions. At these gatherings, which occupy three or four days, original papers and reports of investigations consigned to committees at the previous meeting are read and discussed. An exhibition of manufacturers' supplies is also held at the same time, and new electric cars of all kinds are put on the town lines and run on regular service. Members practically own the town during their stay; the largest hotels are full, rooms being taken by representatives of different concerns as temporary offices. The various companies and firms in the town send in invitations to visit power houses and works, books of tram

Mr. Wilkinson. tickets are distributed gratis, and the telephone companies place their lines at the disposal of members. Time will not allow me to do more than refer to the very pleasant participation I enjoyed in the last convention at Milwaukee, Wisconsin. The papers read have appeared in our own technical Press, and are consequently well known. The supplies comprised car bodies, trucks, motors, controllers, fuses and heaters, track scrapers and sprinklers, steel rails, points and crossings, compressed mica, and overhead line gear of all descriptions; everything that could be put in motion being supplied with electric current. Each member received a small choice souvenir of his visit, the gift of the newly elected president, Mr. Henry Paine.

I now pass on to some of the questions which are absorbing attention, and to describe what I saw of the working of different systems.

The directions in which improvements are sought comprise chiefly—

(1) Better construction of road beds and tracks;

(2) Better provision for the return circuit;

(3) More uniform distribution of potential along the route.

Further, in the power house, the chief questions are in the driving, governing, and safety devices, the best proportion of power between engine and generator, and the problem of fly-wheel inertia.

Beyond these there are the questions of practical and economic systems of delivering energy to cars in cities and crowded portions of towns, such as by the storage battery or underground conduit; and for long-distance transit the use of synchronous or of two- or three-phase motors with transmission of current by underground feeders at high tension.

Some of these questions have given rise to much discussion in America, and most of them have more or less a bearing upon the development of electric traction in our own country. It appeared to me, therefore, that I could in some measure further the progress of the industry in this country by making such observations and inquiries on the present working of tramways in the States and Canada as affected the immediate future; and I looked

forward on my return, to the duty as well as the pleasure, of bringing the results of these investigations before the members of this Institution. Mr. Wilkinson.

During the summer of last year I visited the cities of Detroit and Milwaukee, and in November—on the completion of my official duties at the Exposition—the cities of Toronto, Montreal, Buffalo, Cleveland, Cincinnati, Pittsburg, Washington, and Philadelphia; making also a complete examination of the electric railroad recently erected on the Canadian side of the Falls. From the officials of the various companies whose lines and plant I investigated I met with the greatest courtesy and cordiality, and the expressed wish, not only on the occasion of my visit, but at any future time, to furnish such information as might be desired.

With regard to road bed and track construction there is not much to be said, as the general conditions in America differ considerably from those in our own country. In many cities, and especially in the suburbs of large western cities, the rails are allowed to project above the road bed 1 or 2 inches, making very rough travel for other vehicles. In fact, the iron road is counted of the first importance in inducing people to live further out of town and build on the prairie, while the road for the use of ordinary vehicles is of only secondary consideration. After a few years, as property goes up in the district, a better foundation is put in, and the roads are levelled up to the metals by paving blocks or glazed bricks. Whole suburbs spring into existence in the wake of the electric tramway. Enterprise in promoting schemes is chiefly due to estate holders seeking to raise the value of their property, and it is remarkable that municipal corporations have given away important concessions for very trifling sums. These concessions after a few years generally become very valuable, and bring a good return to those who have sunk capital and taken risk; but it is now becoming more usual for corporations to look ahead and put in clauses that shall let some percentage of the profits come in for the improvement of the streets.

Practice in the western cities of America is chiefly with T, flat, or step rails, spiked down to wooden cross-ties or sleepers; but on the best lines and in most eastern cities the channelled girder rail

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as used in England has been adopted, on account of smoother travel, less noise, and a flush road surface. The English construction of concrete foundation has been followed on some lines, using a 9-inch or 10-inch girder rail. The tendency now in the States is to put in very heavy girder rails (90 or 100 lbs.), spiked to wooden sleepers placed at about 2 feet centres, which allows a good deal of spring in the track, and tends to loosen the bond contacts. Some 72-lb. channel girder rails I saw in progress of laying had grooves 1⅛ inches wide by 1 inch deep. The height and base both measured 6 inches. There was first an 8-inch foundation of concrete, upon which the sleepers (6 inches by 8 inches) were laid at 2 feet 3 inches centres, and then grouted in. Sand was then tamped round the base of the rails to the depth of 2 inches, upon which the paving blocks were laid. The points and special work were of cast steel.

The question of returning the current direct to the power house with as little leakage and loss in voltage as possible, is one of the most important in street railway problems. Excluding for the moment insulated returns, the paths open for the return current from the cars to the power house are—

(1) By the rails and return feeders;

(2) By supplementary wires;

(3) By the earth;

(4) By metallic pipes and cables laid in the earth.

The return feeders include not only those cables connecting the nearest point on the rails to the generators in the power house, but cables brought in from more distant points of the line, as the configuration of the same and the load may require. In this matter everything depends on the position of the power house with regard to the route of the line. The primary object in their use is to lessen the voltage losses at the distant portions of the line; but in some districts their use has been largely extended, in order to prevent electrolytic effects on gas and water pipes. The remedy for the latter is clearly to provide a metallic return of ample conductivity, and while on modern lines improved bonding has done much to effect this, the addition of return feeders has had the desired effect in older and badly

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bonded lines. In Cleveland, Ohio, for instance, I found a very extended use of return feeders, and I was informed by Mr. Charles W. Wason, vice-president and electrical engineer of the East Cleveland Railway Company, that he had resorted to their use entirely on account of electrolytic troubles with the water pipes of the city, with the result that the action ceased, and, in addition, about 25 per cent. of the voltage was saved. Some idea of the advantage of a saving in volts, apart from the consideration of speed of cars, can be gained from the fact that the current reached 3,000 amperes, and that for, say, 50 volts lost on the line every 1,000 amperes means a continuous loss of 70 horse-power. The return feeders in this city are carried overhead, and are connected by riveted joints to the rails at about every 500 feet. In Buffalo, also, I observed an extensive use of return feeders, carried underground with the outgoing feeders within the city limits, but overhead further out.

Coming now to bonding, I have seen many different specimens of this work, and have some samples here to-night for the members' examination. One form of bond joint (Fig. 1) consists of a steel

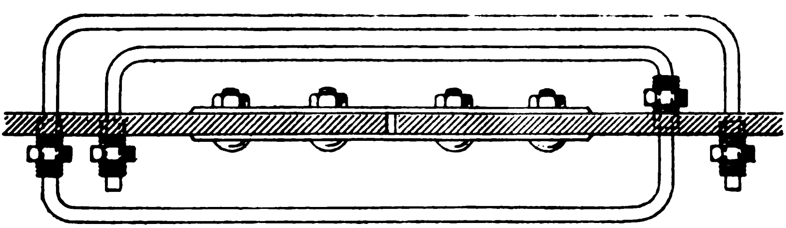

FIG. 1.—Bonding Nipple.

nipple bored to fit the bond wire, and tapered and slotted at one end. This screws into the rail, and the nut screwed up tightens the wire in the nipple, and the nipple in the rail. This was introduced by Messrs. Stern & Silverman, of Philadelphia, and is used on the lines of the Electric Traction Company of that city, the bond wires being passed two or three times through the rail outside the fish-plates to obtain the necessary conductivity.

There are still many very imperfect bonds in use, such, for instance, as that with copper or iron rivets and soldered bond wire

Mr. Wilkinson. (Fig. 2), of which I have a specimen here. In heading the rivet the soldered joint is frequently loosened and the bond rendered

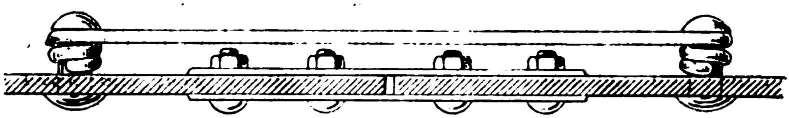

FIG. 2.—Rivet and Soldered Bond Wire.

useless. The channel pin bond (Fig. 3), of which I have a specimen here, is in very extensive use; but a great defect in

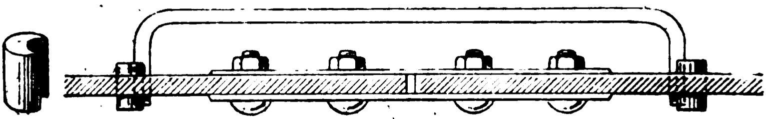

FIG. 3.—Channel Pin.

this device is that it cannot be riveted or made to completely fill the hole, and corrosion takes place in the interstice. The channel pin is used for the double bonds on the Lynn and Boston line, as shown in the illustration (Fig. 4.). Another bond is the taper

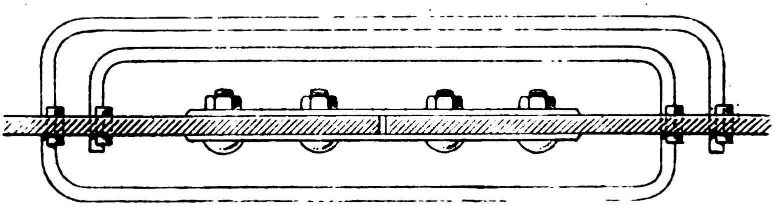

FIG. 4.

spring steel cap (Fig. 5), which is fitted on the end of the wire and driven into a hole in the web of the rail slightly less than its

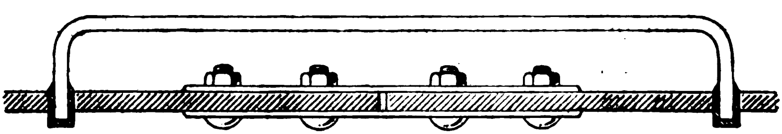

FIG. 5.—Taper Spring Cap.

own external diameter. A similar bush joint, but formed as a sleeve or socket, has been in use some time on double bonds, as in illustration, and promises well (Fig. 6). A considerable improvement consists in making the bond wire in one piece, with

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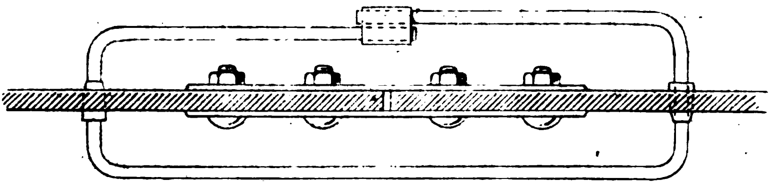

FIG. 6.—Split Steel Sleeve Bond.

shoulders for riveting formed at each end on the wire itself. This device (shown in Fig. 7) is due to Mr. McTighe, of New York,

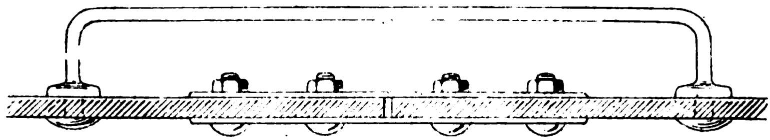

FIG. 7.—Bond Wire with Shoulder Riveted in one piece.

and has been very largely used. The advantages of this plan are, that clean, water-tight, and air-tight solid metallic joints are obtained, and that the bonds can be made of any size wire. Mr. McTighe prefers to use these in short lengths of 12 inches inside the fish-plates instead of the usual length of 30 inches, thus saving 40 to 50 per cent. in bond resistance. The short bond cannot be fixed to the web of the rail on account of the fish-plates, but is either attached to the tread or the base, the latter being the better point of attachment, as the bonds are soon worn away when on the tread. This bond, however, sooner or later becomes loose, owing to the difference in the coefficient of expansion of copper and steel, and this being followed by galvanic action, the resistance, which at first is slight, rapidly increases at the joint. Some provision by which solder could be run in might add to the certainty of this joint, the ductility of the solder taking up the unequal expansion and contraction.

Some of the older lines in the States, laid before the value of good bonding was appreciated, show an enormous loss of voltage from this cause. I was informed that on an old line in Richmond, Virginia, the bonding was done by No. 6 iron wires, and the same bonds used for a recent extension of 2½ miles, with the result that of 500 volts put into the line not more than 210 appeared at the distant end. The matter was investigated in consequence of

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bad working, and good copper bonds substituted for the iron wire, with the result that the loss was reduced to 5 per cent.

Bond wires are subject to corrosion by electrolytic action, especially in alkali soils. The wires consequently become thinner and conduct badly, and some of the current is shunted round the joint to earth, thus increasing the corrosion. Again, when the wires get very thin they become heated, and fuse, thus throwing extra load on other feeders. I was informed that the action was prevented by painting the wires, or coating them with shellac and asphaltum. The section or number of bond wires has, of course, to be increased nearer the power station.

The conductivity of the return circuit has been increased on some lines by the use of a supplementary wire, which is usually of bare copper $\frac{3}{8}$ inch or $\frac{1}{2}$ inch diameter, laid along the centre of the track. Cross connections from all bond joints are made by copper wire twisted and soldered to the supplementary wire, and on double tracks the supplementary wires of each track are connected every 30 yards. I saw new lines being laid with these wires in Chicago and Detroit, but I have also seen lines freshly opened up where the supplementary wires were considerably corroded, and was informed that their life was about two years. There were so many joints in the system, the wires used were so small, and were of such poor conductivity in comparison with a well-bonded rail, that the expedient appeared to me to be temporary and unreliable. In fact, I gathered that one of the chief uses of the wire was that its presence allayed to some extent the anxiety of the city authorities, otherwise harassed by water and gas pipe corrosion.

I next come to the earth as a return. I found that earth connections were made on most lines at their lowest points and at the power house. Such connections were made by sinking old car wheels or driving rails or pipes in moist earth, and making as good a connection therefrom to the rails as possible; but, from all I could learn, not much reliance was placed on such returns. The extremes of weather no doubt have something to do with it, as hard dry earth is a bad conductor. Even wet mud in comparison to the rails is a poor conductor, as is evidenced by the brilliant arcing at the wheels of cars running on a muddy rail. In the

Street Railway Journal for last December, some tests by Mr. James D. Rostron, chief engineer of the Union Railway Co. of Chester, Pa., bearing upon the conductivity of the earth as a return, were published. Mr. Rostron obtained an average of 285·5 amperes through the track and supplementary wires, 12·8 amperes through the city water mains, and only 0·51 through the earth plates sunk in creeks. If this is confirmed by further tests, it shows that the conductivity of the earth as a return is not high, but depends upon the presence of metallic conducting matter within it. While in Chicago, I made some tests to ascertain the approximate conductivity of the earth, and the difference of potential required to force current through pipes not metallically connected to a circuit. I laid some lead and iron pipes in earth, and at 1½ inches distance above them I placed two iron plates as electrodes, 6 feet apart. Each plate offered 20 square inches of surface, and the current passed partly through the 6 feet of earth from plate to plate through clay, sand, and mould, and partly through 1½ inches of earth at either end (clay and mould), and along the pipes (Fig. 8). I expected the resistance of the latter Mr. Wilkinson.

FIG. 8.

part would be almost *nil*, and, as I had 120 volts at disposal, I first put a resistance in series of four 105-volt lamps in parallel. I found, however, that the earth resistance was far more than I anticipated, and I removed three lamps with very slight increase of volts on the remaining one. The current was then half an ampere, and the earth absorbed 20 volts. A few days after, I obtained current from a 200-volt circuit, and put the four lamps on again. I then had 2½ amperes, with 100 volts absorbed by the earth. After keeping the current on for two weeks, the pipes were taken out, and were found to have a

Mr. Wilkinson

pitting of white scale in places at the negative ends. The scale was in white lumps, which, upon being scraped off, revealed the starting of little holes about 3-32nds of an inch diameter. This proved that some of the current, if not almost all, had passed by the pipes through the 3 inches of clay and mould. While I attribute this high earth resistance to the clay, which had set hard, I am still of opinion that the earth has more resistance than is generally imagined, and that to attract current in anything but very minute amounts from a well-bonded rail to earth requires special conditions, such as deeply sunk plates, metallic connection to pipes, the ground saturated with moisture, or an excessive density of current in the bonds. I was informed by Mr. C. H. Morse, the city electrical engineer of Cambridge, Mass., that in some tests he made at Saginaw, Mich., for the gas company there, he was surprised to find that pipes were eaten away in two or three months under a return current which did not exceed 500 amperes. The soil was, however, very moist clay, and the rails were connected to earth plates.

This leads me to the question of the use of city water mains and gas pipes as return conductors. At Milwaukee, Wisconsin, where this was first brought under my observation, I was informed by the city engineer, Mr. G. H. Benzenberg, that considerable difficulty had been experienced. City water mains and service pipes had become corroded in from two to three years, the action being most marked near the power stations. An attempt was made by the passing of an ordinance to stop the tramway companies connecting their rails to any pipes whatever; but the matter had gone too far, and the benefit to the latter companies in reducing volt losses by so doing was so marked that the practice was still carried on in spite of this ordinance. The matter was at length remedied by obliging the companies to make good connections to the water mains at the nearest points to the power house where the current left the pipes, such connections being taken right on to the switch-board return. The point proved was that pipes were affected at points where the current left them, like anodes in an electrolyte, and that protection could be afforded by putting a conductor instead of the electrolyte to earth. In this

way pipes in an affected district could be thoroughly protected, but at considerable expense. It was evidently better to put such conductors to the rails direct, and not connect to pipes at all. Mr. Wilkinson.

I saw several specimens of lead and cast-iron pipes that had been corroded and cut out, and have reproduced a photograph of some of the larger pipes in Fig. 9. Mr. Benzenberg informed me that the matter was cropping up in several cities, and that at the meeting of the Association of Water Works Engineers last September great prominence was given to this subject.

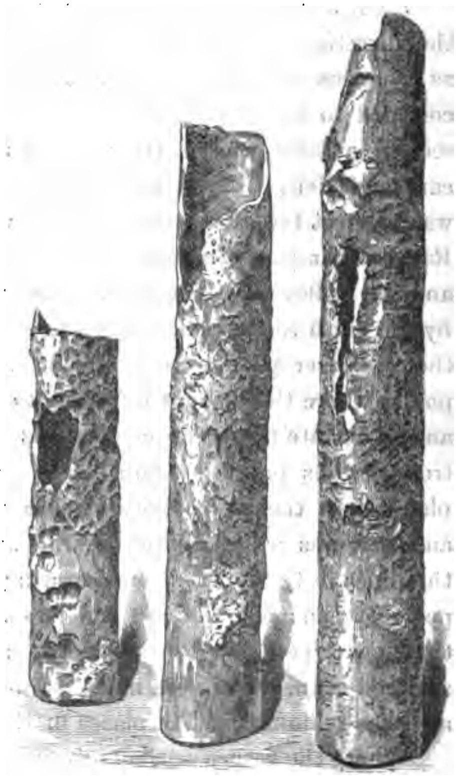


Fig. 9.

I was, unfortunately, unable to visit Boston and Cambridge and see the extensive electric tramway systems and the enormous power houses there, but, partly by communications with Mr. Morse, and partly from Boston engineers who visited the Exposition, I was informed of some of the experience gained on these points in those cities.

The amount of return current to deal with can be imagined when it is known that the West End Railroad Company have an output of 12,000 horse-power. This is distributed from three stations, of which the one at East Cambridge alone has an output of 6,000 amperes. Considering, also, that of 270 miles of track more than half is of 56-lb. and 70-lb. rails, laid years ago, and either bonded indifferently or not at all, it is not surprising that pipes and cables which were metallically connected to the

Mr. Wilkinson. rails in places should be affected. The information I have from authentic sources is that the water and gas mains and lead-armoured telephone cables suffered to a very great extent. The Bell Telephone Company tried earthing their cables by connecting them to lead plates buried in manholes, but this afforded no protection from the very heavy currents passing.

A curious experience was gone through in this city in reversing the direction of current. The supplementary wires resorted to as a means of increasing the conductivity of the track became corroded to such an extent that when a car passed an affected section a difference of potential was set up between rails and earth sufficient to cause shocks to people and horses. This effect was so great towards the end of the year 1891 that the West End Railroad Company reversed their current, making the rails positive and the trolley wires negative. The current then left the station by the earth connections, including all piping in the station, and the condenser pipes were attacked. Other troubles arose at fresh points where the current left the city pipes to get on to the rails, and to obviate these the current was again reversed, making the trolley wires positive again. The action was then noticed in places near the power house where the current left the pipes, and this was overcome by making heavy copper connections to the pipes in these places, and carrying the same to the negative poles of the generators in the power house. It was also found that gas pipes had to be treated in the same manner, and soldered connections were made between gas and water pipes in all large buildings and in places in the streets.

Where the return currents reached 12,000 to 15,000 amperes the ground along the track was found to be heated, and return feeders from heavily loaded points had to be used. These were tapped down near the station to underground pipes, as it was found that if this was not done the pipes entering the station were at a difference of potential sometimes as much as 5 volts—sufficient to heat an iron wire between them, with consequent danger of fire.

Mr. Morse, in a comprehensive paper on this question before the New England Water Works Association at Boston, Mass., in

January, 1893, describes having tried covering pipes with cracked stone, and in muddy places bedding them in cement, as a protection; but this was costly, and of no use unless done completely over the whole pipe system Mr. Wilkinson.

The trouble with electrolysis in this city I take to be due to the exceptionally large outputs and indifferently bonded rails. The city has purchased experience at heavy cost, but which has been of benefit to others. The adoption of return feeders and good bonding on later lines, with freedom from these troubles, has been one result. At the same time the congested condition of current-density has raised the question of some other means of distributing current to cars. One method about to be tried in Boston and Cambridge is the three-wire, or zone, system. The rail or earth return would then be the neutral wire, and the sections of trolley wire would be alternately positive and negative. The section of the trolley and feed wires within a circle of, say, one mile of the power station would be at 500 volts positive potential, and the outer sections 500 volts negative. Further, this section might be again divided into half- or quarter-mile zones, or further subdivided, thus practically preventing any flow of current in the earth. By this means the potential and volume of current would be distributed more evenly over the circuit, and there would be less concentration of current at power houses. The current would return by the insulated feeders. On the other hand, there would be a current flowing through the rails or earth from the cars on one section to cars on another; but this would supply power to twice as many cars as on the two-wire system. On rare occasions, if all cars happened to be banked on one section or a set of sections at one potential, the action would be like a two-wire system, and the current return by rails and earth to the station. The spark, on passing an insulated junction between trolley wires of opposite potential, could easily be deadened by a small high-resistance shunt across the break. The general advantage of such a system cannot be pronounced upon until it has been tried; but, as far as the return current is concerned, it appears to offer considerable relief.

I should mention here that in Boston the experiment was

Mr. Wilkinson. tried of welding the fish-plates to the rails, thus making a permanent and reliable electrical joint. The Johnson Company, after obtaining good results on 3,000 feet of experimental track, were empowered to weld 16 miles for the West End Street Railway Company, and during two years the rails have shown no tendency to buckle. During this winter, however, I learn that the rails have broken into sections of a few hundred feet, due to contraction, the fractures always occurring near the weld. I believe, however, that this is the right method, and may still be modified to give successful results. The bond should be made outside the fish-plates, allowing a loop for contraction, and the poles of the welder should be arranged to distribute the heat gradually from the weld, and so prevent abnormal strain of the metal. The absence of dissimilar metals in the joint ensures its permanency as long as the rail itself lasts, both as regards local action and expansion.

Reviewing the circumstances attending electrolytic action, as far as I have been able to gain information on the spot, I find that these troubles have chiefly been traced to insufficient conductivity at the rail joints, and to the want of proper return conductivity in the shape of feeders. When traffic on the lines increases, or extensions take place, and the increased power is drawn from the same supply station, either the bonds must be increased in sectional area (if they have not been put in at first of sufficient size for ultimate demands), or return feeders must be run to relieve the bonds, otherwise the consequence will be that the current will be crowded out of the rails into the earth. This is what has actually taken place on some systems in the States, and the current has been allowed to take its own course until the heating of rail joints and bonds has drawn attention to the want of conductivity. This crowding out occurs on the main or trunk lines, into which several branch lines converge. On simple lines, or those from which no branch lines radiate, it is less liable to occur, as even with an excessive volt loss per mile the density of current is well within the capacity of ordinary single bonds. Take, for instance, a line of three miles of double track between A and B (Fig. 10), and consider it first with

no branch lines. Say we have a three-minute service of cars, and the average speed, allowing for stoppages, is $7\frac{1}{2}$ miles per hour. The cars will then be three-eighths mile Mr. Wilkinson.

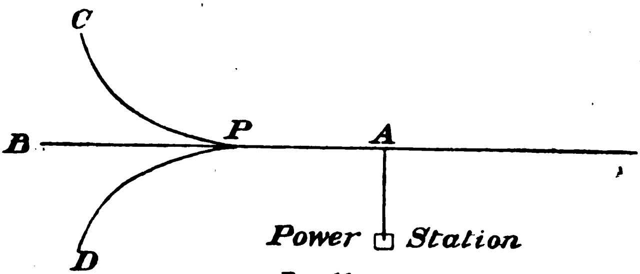


FIG. 10.

apart, and there will be eight cars on each track. With two motors per car the current will be about 25 amperes at maximum speed; but some cars will be starting, and using 100 amperes, and we may take a time average right through of 50 amperes per car. The maximum current returning to the power station from A will then be 800, and the maximum at B 100 amperes. The resistance of copper bonds varies according to method of bonding, length and size of bond wire, and whether it is double or single. Per mile run of rail the bonds may be from one-sixth to twice or three times the resistance of the rail. Taking a 70-lb. rail with low-resistance bonds, say of No. 000 gauge, 12 in. long, and fixed double, we shall have the resistances per mile of rail 0·0344 ohm, of bonds (176 to the mile) 0·0056 ohm—total, 0·04 ohm, or 0·01 ohm for the double track. The voltage loss will therefore be 1 volt per mile per 100 amperes. Working this out for the varying strength of current on different portions of the return, we have a loss of 10 volts on $1\frac{1}{2}$ miles from A to P, and 4 volts on an equal distance from P to B—total, 14 volts.

Suppose now a branch line is laid from from P to C, also of $1\frac{1}{2}$ miles, with cars at same speed, and same rate of service. This will then absorb 4 volts, but the loss between P and A on the trunk line will be increased to 19 volts; and if another similar branch, P to D, is added, the loss on the trunk line becomes 28 volts, or a total of 32 volts on the whole. When it is

Mr. Wilkinson. considered that with a theoretical continuous rail without bonds this loss is only reduced by 5 volts, it will be seen that to prevent waste of energy, quite apart from reducing current-density, we must connect return feeders to the rails on the trunk line.

Now, considering the current-density, we have in the trunk line, when the two branches are in operation, a current of 1,300 amperes at P and 2,400 amperes at A. The maximum current per rail is therefore 600 amperes, and this on 7 square inches gives a density of 86 amperes per square inch of rail (equivalent to 510 amperes per square inch of copper). This could be increased four or five times before any sensible rise of temperature would take place in the rail; but, considering the bonds, whose sectional area per rail is 0·262 square inch, we find we have a density of 2,290 amperes per square inch. It would probably take very little increase of current beyond this to cause heating of the bonds and crowding out of current into the earth; and yet the bonds on many lines in the States have less sectional area than the one cited, and the currents are from twice to four or five times as great, producing far higher densities in the bonds than they can carry. I am convinced that this is the cause of most of the electrolytic troubles in the States. Trunk lines, into which a number of branch suburban lines feed, are frequently of considerable length, and cars necessarily move slower in consequence of their accumulation on one line. Not only on account of the number of cars, but also because of their slower speed and frequent re-starting, the current put on to the rails is very much increased, and the density in the bonds becomes far more than they can carry. We have seen that it is not a question of resistance or conductivity of the bond, as the voltage loss beyond that on a perfectly continuous rail is only increased by about one-sixth of that lost on the rail, and therefore the increasing of the conductivity confers no appreciable benefit so far as reducing voltage is concerned. The question is one of sectional area of bond with reference to the ultimate maximum current it is expected to carry, and this I think should not exceed 2,000 amperes per square inch. The sectional area of the bond refers as much to those portions in

contact with the rail at the joint or joints, as to that of the single or double bond wire itself. Mr. Wilkinson.

I cannot leave this portion of my paper without a tribute to the pioneer work and enterprise of our transatlantic cousins. They meet every difficulty squarely in the face, and in spite of all obstacles "get there all the same." Our designs must necessarily comply with more conditions than are exacted in America, but when our difficulties have been the same our friends have generously been ever ready to impart their experience.

I will only touch upon one of the Board of Trade Regulations, viz., rule 7, similar to which is rule 9 of the Draft Regulations for Underground Electric Railways. In its draft form rule 7 exacted that the original or recorded resistance of the return should be maintained constant, with a maximum allowable increase of 15 per cent. In its amended form the same idea is carried out, but the element of current-strength is included, namely, the product of resistance with current—that is, the difference of potential between extreme ends of the line—and this must not exceed 7 volts. The framing of the rule, I take it, was aimed at securing a low density of current in the rail, thus preventing the crowding out of which I have spoken, and placing the pipes of gas and water companies beyond all harm. It seems to me that this end is not altogether accomplished, because with a given difference of potential, however low, it is possible to have a very high density in the bonds, with a very low one in the rails. In other words, under complete compliance with the rule the bonds may be carrying far too high a density and shedding their current into the earth. Referring for a moment to the example considered above, a heavier rail might be laid with bonds of less sectional area and still not alter the difference of potential at the ends of the uninsulated return. A 90-lb. rail would have 0·0268 ohm per mile—that is, 0·0076 less than the 70-lb. rail—and this difference could be made up of smaller bonds of less carrying capacity. By using single bonds of No. 00 gauge (0·104 square inch section) instead of double of No. 000 (0·131 square inch section), this is obtained very closely, and we have the resistance per mile of rail 0·0268 ohm, of bonds 0·0142—total, 0·0410, or 0·01

Mr. Wilkinson.

ohm for the double track, as before. The difference of potential at the ends of the uninsulated return for the same currents is therefore unchanged, but the densities are very different. That in the rail is reduced to 66 amperes per square inch (equivalent to 400 amperes per square inch of copper), while that in the bonds is increased to 5,760 amperes per square inch—nearly three times more than the limit I alluded to. Some of this density is relieved, of course, by the conductivity of the fish-plates, but this is of such a variable and unreliable nature that it should not be reckoned upon. Density, of course, can and should be relieved by return feeders, and these would be necessary on most lines of any extent to keep the volt loss within the required limit; but even with return feeders and low density in the rails I have shown that there might still be too great a density in the bonds, if these were not of sufficient section. Further, it appears to me that a limit of volts per mile would be equally effectual and more workable than a certain limit for lines of all lengths and traffic.

Having endeavoured to put before you the results of my observations, I may say that I am convinced that bonds should be of sectional area proportioned to load, which will materially lessen cost of return feeders; and, secondly, at points on the rails chosen with regard to load, return feeders should be connected of such section as to relieve the density of current in the rail. By return feeders I do not mean supplementary wires or connections to water pipes, but metallic conductors either above or below ground, not necessarily insulated, but connected direct from the rails to the power station. Supplementary wires are of no use unless increased in section as the current increases, so as to keep an approximately constant density, and this I have never seen done; while making connections to water pipes is a makeshift at best, and one that shows a want of good design. I believe that by designing the return circuit of electric tramways in the manner I have indicated we shall keep clear of electrolytic troubles upon gas and water pipes, and ensure an unhandicapped career for electric traction in this country.

I now come to systems in which the return is insulated from earth, namely, those using the overhead double trolley and the

underground conduit. I was much interested in the double-trolley system working in the city of Cincinnati, Ohio, and wished to ascertain whether the insulation from earth was well maintained, and of sufficient benefit to warrant the use of such a system. I received the greatest courtesy during my stay in that city from Mr. George Hornung, civil engineer; Mr. H. P. Bradford, of the Cincinnati Inclined Plane Railway Company (using single trolley); Mr. Kilgour, of the Consolidated Street Railway Company (using double trolley); and Mr. Wm. J. Clark, of the General Electric Company, with whom I visited the power houses and inspected the lines. I shall not easily forget my first impressions of double-trolley working, as I passed through Fourth Street to Fountain Square, in the busiest part of this city, on the morning after my arrival: cable cars, double- and single-trolley cars, and horse cars followed each other in rapid succession, often on the same track; but the most startling thing was the immense amount of trolley and span wires suspended over the roadways, with all the necessary adjuncts of insulators, guard wires, frogs, and separators. I watched several of the double-trolley cars rounding curves, and observed that the trolleys frequently jumped off the wires, and that the conductor on the car had to keep his eyes on the trolleys and steer them with the cord on passing curves. Mr. Wilkinson.

A good deal of extra complication was due to the presence of single-trolley wires along double-trolley tracks, and the necessary use of span wires in the narrow streets of the city. Out in the suburbs, however, the double-trolley construction was seen to better advantage, as the wide roads allowed for centre-pole construction. The rumour prevailed in other cities that the double-trolley system was on its last legs; but, so far from that being the case, I found that the Board of Affairs of the city had just granted the company powers to lay 50 additional miles of double-trolley track, the mileage then in operation being about the same in extent. No doubt the rumour arose from the fact that this was the only city in the States (with the exception, I believe, of a small line at Rochester) that employed the system, and the history of its rise in Cincinnati was remarkable. The

Mr. Wilkinson. first to be put down was a single-trolley line, which was opposed by the telephone company on the ground of interference. Litigation resulted in favour of the latter company; but the tramway company appealed on two or three judgments to higher courts, and eventually got a verdict in their favour. During the progress of this litigation a new tramway company was financed by those most largely interested in the telephone company, with the view of proving that double-trolley was the only way out of telephone interference, and to force the hands of the single-trolley company. Mishaps in winter, however, in the earliest days of its adoption, favoured the final appeal above alluded to, and ended in metallic returns being put on telephone lines instead. The position remains unaltered to-day, and both trolley systems prosper.

I found that the insulation of the double-trolley lines was good, so far as the overhead construction was concerned; but that it frequently broke down at the motors, thus putting one or other trolley line to earth. To show what kind of insulation existed, my friends and I boarded a single-trolley car, stopped it, and pulled the trolley arm off the single wire on to one of the double-trolley wires; the lamps lit up inside the car showing an earth on one main of about 200 volts. The leak was not sufficient, however, to run the car, but it appeared that in wet weather this was frequently done. Again, in the Hunt Street station, an earth indicator was permanently fixed, consisting of two rows of five lamps, in series. Each row was connected between one of the trolley wires and earth, and I observed during my visit to this station that one of these rows was lighted up to nearly full candle-power. The light was fluctuating slightly, which appeared to indicate that the earth was on a moving car; at all events, I was informed that such earths were of frequent occurrence, and went off as suddenly as they came on, but did not affect good working. Earths on a line were "spotted" after all cars were home for the night by switching off one section after another while full power was kept on. The leakage current on two lengths of twelve and nine miles of double track joined in multiple with all cars off was 12 amperes, under the full pressure of 500 volts.

The cost of street work in America for double-trolley construction is about £650 per mile, the items being as follows:— Mr. Wilkinson.

	£	s.	d.
100 iron poles	260	0	0
100 hangers...	17	0	0
100 solder cars	5	0	0
70 strain insulators...	4	9	8
3,000 feet span wire	12	0	0
10,560 feet No. 1 copper trolley wire ...	84	9	8
5,280 feet No. 0000 feed wire	211	4	0
25 3-foot cross arms	0	15	0
50 glass insulators	0	12	0
200 sacks of cement	12	0	0
15 loads broken stone	4	10	0
5 loads sand	0	15	0
Labour and superintendence	45	0	0
	£657	15	4

This is about one-third more than the cost of single-trolley construction; but against this must be put the dispensing with bonds.

While this system is out of place in cities and confined thoroughfares, and, indeed, wherever span wires must be used, I believe it offers some advantages for heavy passenger traffic or goods traffic in suburban districts. It offers immunity from leakage currents to earth, for such can only take place when more than one earth is on the line. There is therefore no anxiety as to electrolytic action on pipes, even with the heaviest currents, no interference with telephones, and it is not necessary to bond the rails. With neat iron poles and ornamental cross brackets the line is not at all unsightly in the centre of the road. On some lines the appearance is improved by clusters of incandescent lamps, with reflectors, on every second or third post, and all feeder cables kept underground. The only objection to the system is the amount of overhead work at curves, turn-outs, and crossings; but it certainly holds its own in Cincinnati for smooth and rapid transit, and has proved itself a commercial success.

Mr. Wilkinson.

On the table are some photos of the city for members to examine, showing some of the overhead construction. I have here also a specimen of the Kisinger splicing tube, by which breakages in trolley wires are rapidly repaired (Fig. 11). I witnessed two

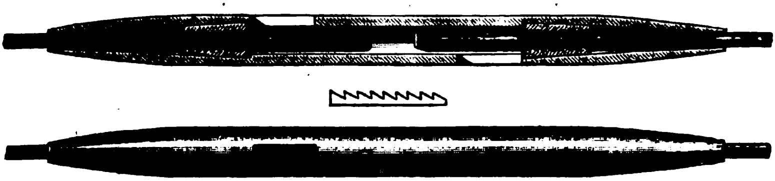


FIG. 11.

breakages in one street, which took only five minutes each to repair by means of these tubes. The broken ends are pulled up and put in the tube, and then the dogs slipped in through the slot. When the tackle is slacked off the ends are locked, and an excellent electrical joint made without soldering. For working at the wires an emergency waggon, with folding ladder, is used, and joints have been made in 3½ minutes, including picking up broken ends from the street.

I now pass to the consideration of underground conduit lines, also using an insulated return.

During my stay in Chicago, the extensive plant of the North Side Tramway Company, consisting of gas motors fixed to special cars, suffered almost complete destruction by fire. As there had been serious complaints of the noise and smell of these gas motors, the company endeavoured to get a clause revoked in their franchise which prohibited their using an overhead trolley line. Their intention to equip their line in this manner, however, met with great opposition from property holders, tradesmen, and insurance companies, and the clause was not struck out by the City Council. Previously, however (in March, 1892), in consequence of this clause, the company had equipped about a mile and a quarter of their line electrically with an underground conduit on the Love system. I found this in successful operation last year, and made a few notes on it, which I hope may prove of interest. The illustrations (Figs. 12 and 13) show sections of the line construction and roadway. The depth excavated below the road

level is only 2 feet, involving no trouble or expense while laying the track in diverting pipes along the route, as is so often necessary in laying a cable track. Mr. Wilkinson.

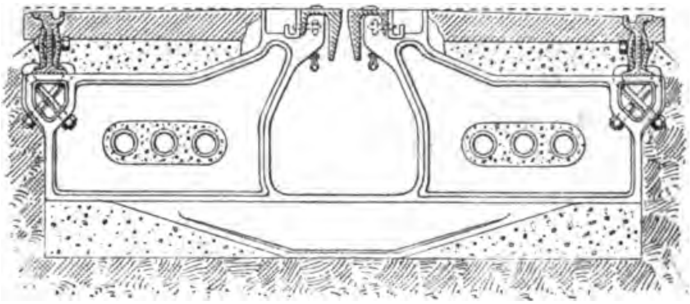


FIG. 12.—Yoke.

The slot rails are in 32-foot lengths, and bolted to the yokes every 4 feet. Pockets, or small hand holes, are provided in the road over every bolt, so that, if required, the rails can quickly be removed, and the conductors and insulators exposed to view. The slot rails are spaced for a $\frac{5}{8}$-inch slot, and shaped with 5-inch

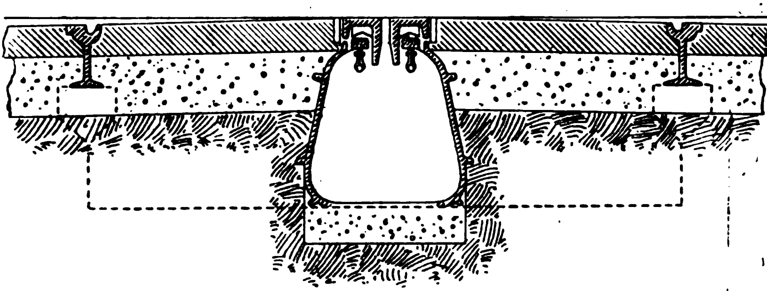


FIG. 13.—Conduit.

inside lips, so as to shed water into the conduit clear of the wires. The track rails are held by claw bolts to the yokes, as shown, and the whole construction rests on a bed of 6-inch concrete, and is packed round with concrete as a bed for the stone blocks of the roadway. In the webs of the yokes spaces are left for laying pipes to contain feeder wires, the conductors being in sections of 500 feet. The conductors are of bare copper rod, nearly half an inch diameter, grooved longitudinally, and suspended from loose-fitting gun-metal clips, or ears, as shown (Fig. 14). The stalk of

Mr. Wilkinson.

each clip is secured to a block of pressed mica or other insulating material, B, which is suspended from two shoulder bolts bolted to the yoke. To allow for expansion of the conductors, the blocks

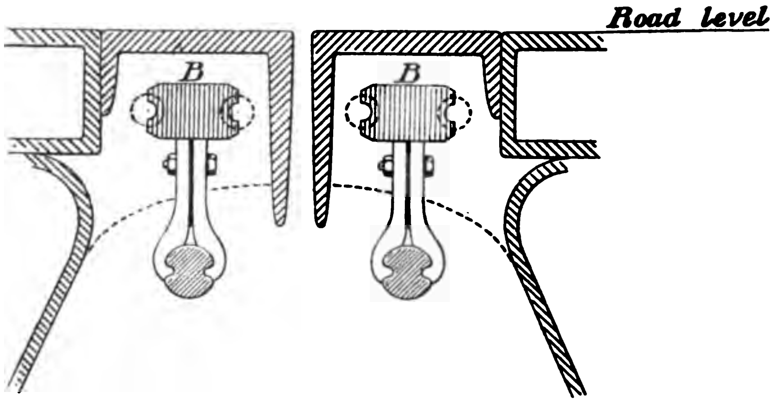


Fig. 14.

are free to move about 2½ inches on the rods. With the trolley wheels travelling in the direction of the arrow, it was found that the blocks shifted a little in the reverse direction every time the trolley wheels passed, and it was necessary to put stops at S (Fig. 15). The insulators are fixed to every alternate yoke, at a distance apart of 9 feet on the straight run. On curves, however, they are closer together, and stronger supports are used, the conductor being circular in section, and clipped in ears having circular jaws, as shown in Fig. 16, which are afterwards filed round below, so as to offer no resistance to the trolley wheel.

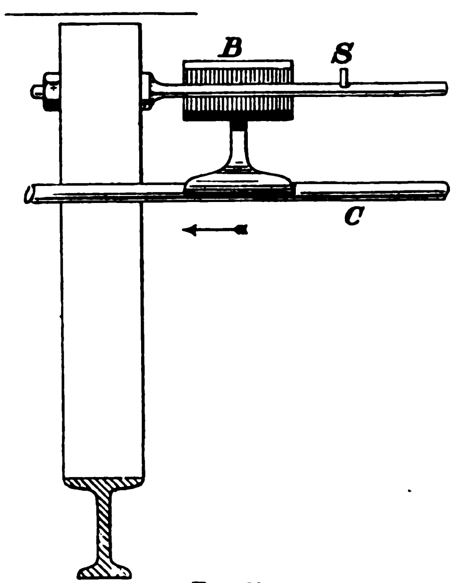
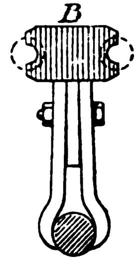


Fig. 15.

The trolley wheels bear

upwards on the underneath side of the conductor, exactly as in overhead lines. The illustration (Fig. 17) shows the arrangement with spring for keeping tension on trolley wire, and back stop for keeping the wheel in place on the wire. The plate travelling in the slot and supporting this gear is of half-inch steel, and 4½ inches wide. The trolley arms are jointed to take lateral as well as vertical movement, and thus follow every change of direction of the conductors. Mr. Wilkinson.



The line in Chicago is in the form of a triangle a little over 1¼ miles long, with three straight lengths and three curves, and in one place it crosses over the cable line. The motor cars (which also carry passengers) haul the trailers with passengers left by the Lincoln Avenue

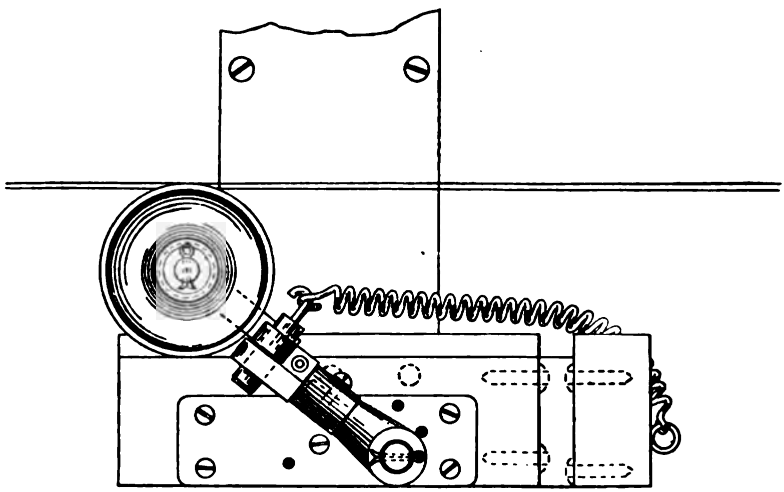


FIG. 17.

cable cars and North Halstead Street horse cars round Fullerton and Webster Avenues. This was the first line on this system, and, as might be expected, some difficulties were met with. These were chiefly due to the breakage of insulators, expansion of conductors, and snow and ice in the conduit. Boys were also a nuisance, stuffing wire into slot, which jammed the trolley wheels and short-circuited. I found that in July last

Mr. Wilkinson. there had been five stoppages, two in August, and none at all the following three months. Two of the stoppages were, however, due to burnt-out armatures. Brushes were used attached to cars for sweeping out water and dirt from the conduits into sump-holes every 100 feet, which were afterwards pumped out by hand. Water gave no trouble at all, except when it froze in the conduit. Wide extremes of temperature are met with in Chicago, being 15° to 20° below zero in the winter, to 90° in the shade in the summer, and expansion gave a good deal of trouble at first, especially at curves, where the conductors sagged till they nearly touched the side of the iron conduit, upon which the trolleys made earth and short-circuit by touching the sides. This was overcome by dividing the conductors into sections of 500 to 600 feet, and covering the adjacent ends with a long sleeve. Powerful compressed springs on either side of the sleeve were used as shown in the illustration (Fig. 18), which drew the ends together and took up the expansion.

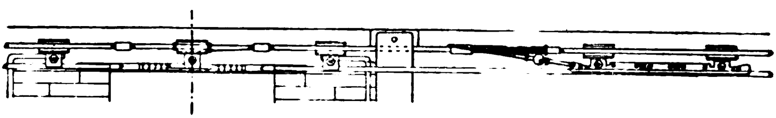


FIG. 18.

At the Milwaukee Convention Mr. M. D. Law read a paper on this system as now operated in the city of Washington (district of Columbia), in which he mentioned the improvements introduced by the Rock Creek Railway Company using the system in that city. I subsequently saw this line at Washington, and found the construction perfected in many details, and the system giving completely satisfactory service, uninterrupted since its inauguration in March, 1892. The line was a credit to this well laid out city, and anyone who could see the smooth and regular running of the cars, with no overhead wires, would say there was a great future for such a system in city traffic. The line of the above company extends some 6½ miles in the suburbs with the overhead trolley system, but at the city boundary it changes to underground trolley. The change from one to the other only involves fixing the trolley bar and switching off the earth con-

Mr. Wilkinson.

nection, which I timed to take 20 seconds. The line then continues along U Street for 1½ miles with double track. On the return journey, close to the junction, the cars have to take a sharp curve, and take an ascent of 1 in 40 at the same time, which they do easily. The insulators and supports at the curves are all strengthened, and the conduit is made 20 inches deep by 14 inches wide, the extra width allowing ample clearance between the wires and the sides of the conduit. The yokes are also put at 4 feet centres instead of 4 feet 6 inches, and the conductors are of ⅝-inch hard-drawn copper. A separate power house was erected to supply the underground system, as it was desired by Mr. Law and Mr. Herbert Claude, the engineers to the company, to thoroughly test the system. Leakage to earth, as shown by a voltmeter between the conductor and earth, was only 0·1 per cent. even in the stormiest weather, and the ammeter remained dead at zero when the full E.M.F. was on and the cars all off. In the wettest weather it was a common thing to find dusty insulators and perfectly dry conductors on removing the slot rails; this condition being due to the natural draught in the conduit and the umbrella nature of the slot rails. On two or three occasions, however, severe rain storms had flooded the conduit and immersed the wires, but the cars ran without delay. With four fully loaded cars on the line the drop was only 3 volts. The trolley wires were in sections, with main and return feeders, switches, and cut-outs to each section, placed in manholes every 500 feet on the straight run.

I have here copies of two Bills which have recently passed the House of Representatives, authorising an extension of tramways in the city of Washington, in which the system of underground conduit I have just described is to be used. The section of the Act incorporating the Washington Traction Company which refers to the system reads as follows :—

Sec. 2. "That the motor power shall be the underground "electric, such as is now in use on the U Street branch of the "Rock Creek Railway, on all of its road east of Rock Creek, "while the overhead trolley shall be used upon that part of the "route north-west of Rock Creek *until such territory shall be*

Mr. Wilkinson. "*built up* and the District Commissioners shall deem it proper "that the wires shall be placed underground."

The other Act empowers the Brightwood Railway Company of this city to extend their lines within the city, using the above system.

It has been proposed to use synchronous, two-phase, or three-phase motors for tram-cars, chiefly with a view to economy in the transmission of energy, but also with the object of avoiding electrolytic troubles. There are advantages to be considered in the use of alternating currents, but it would involve the carrying of line and return close together in the neighbourhood of telephone lines. A tram-car fitted with a three-phase motor, said to be the first one so fitted, was exhibited by Messrs. Siemens & Halske in the Electricity Building at the World's Fair. The motor was four-pole, of 20 H.P. nominal, but capable of working up to 60 H.P. at 500 to 600 volts and 1,400 revolutions. The reduction gear was enclosed in oil.

I now come to some points in power house plant. Most of the stations I visited had large cross or tandem compound horizontal condensing engines, the average units being of 500 H.P., driving 200-kilowatt generators by belts. These were usually compound machines, to give 500 volts on open circuit to 550 on full load, and had the intermediate connection taken from the brushes to the switch-board for coupling machines in parallel. In allowing for "drop" a good deal depends upon the site of the power house. In the heart of a city, where there are a large number of pedestrians and vehicles, the cars must of necessity travel at slow speed, and do not, therefore, require the full pressure, while in the suburbs speed is a matter of importance for business men coming into and leaving the city; and in Cincinnati it was particularly necessary to keep the pressure up, owing to the hilly nature of the suburbs. The power houses, I found, were built in the suburbs in situations most suitable to deliver highest pressure where most required. Short-circuits being of very frequent occurrence, magnetic cut-outs were placed on the feeder and dynamo mains at the switch-board, and in some cases on the machines as well.

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With built-up fly-wheels of the ordinary type, it is well known that the maximum linear speed of the rim must not exceed a certain limit of, say, 6,000 feet per minute. Centrifugal force acting radially outwards tends to bend those portions of the rim lying between spokes, putting the outside of the rim in tension and the inside in compression. What the stresses due to bending actually are need not be gone into here, but it is evident that the safe factor between bending moment and circumferential tension of the rim rapidly diminishes as the limiting velocity is exceeded, and from this cause wheels occasionally fly to pieces without any previous warning. The large amount of energy stored in these 25-ft. and 30-ft. fly-wheels answered the purpose of keeping the volts up under sudden increases of load, but were somewhat a cause of anxiety when short-circuits came on. Either the magnetic cut-out did not act quickly enough and the inertia of the driving power kept the dynamo up to speed and forced it to a burn-out, or the engine raced to a dangerous extent on the quick withdrawal of full load. Some instances of these came under my own observation. At the Hunt Street power house in Cincinnati, where there are intermediate lines of countershafting between engines and dynamos, I noticed some repairs being effected, and was informed that seven pulleys on one line of countershafting had flown to pieces on the occasion of one main engine racing, and that the broken pulleys had smashed an equivalent number of dynamos which they were driving. I was then shown an ingenious arrangement that had since been added to the Corliss cut-off gear, in preparation for the next occasion of racing, by which steam could be instantly cut off the engines by pulling a cord which came over a pulley on the ceiling. These cords were dropped down at various points in the station, so that a man, say at the switch-board, could instantly stop any engine. Pulling the cord released a weighted lever, which moved a cam into such a position under the trip gear that steam was completely shut off during the whole of the stroke. At the time of my visit to the Atlantic Avenue Street Railroad power house in Brooklyn, broken parts of one of the large fly-wheels, together with a generator, were just then being taken out through an opening in the station wall, which, with part of

Mr. Wilkinson. the roof, had been demolished by the flying pieces of a racing engine. The facts were fully reported in the American Press at the time, and the engineer in charge was highly spoken of for the manner in which he endeavoured to avert the catastrophe. On account of the uncertainty of cut-outs it was generally considered that the generators should be under-engined, thus allowing a margin for overload.

I found, on the other hand, that some of the more recently planned power stations were equipped with direct-coupled plant; and the tendency of advanced practice in America, if one may take the plant at the World's Fair as an indication, was certainly towards direct driving. The General Electric Company, who completely equipped the very successful elevated electric railroad of three miles in extent through the Exposition grounds, used for the most part generators coupled both to horizontal and vertical engines; while the Westinghouse Electric Company supplied power to the moving sidewalk from a large dynamo taking the place of a fly-wheel between the high- and low-pressure sides of a cross-compound horizontal engine. This company also exhibited a 160-H.P. generator direct-coupled to a Westinghouse high-speed engine, such as regularly used in their power stations.

I also saw well-arranged direct-driven sets in the power houses at Milwaukee and Cleveland. At the former place there was a very large Edison plant, with boilers on an upper floor and engines below. The engines were of 600 H.P., vertical, triple-expansion, condensing, each driving two 200-kilowatt generators. At Cleveland the power house of the Cleveland City Railway Company contained four vertical triple-expansion condensing engines, by the Globe Manufacturing Company of Cleveland, of 560 H.P., three driving two 190-kilowatt four-pole generators each, and one driving one six-pole generator; the maximum output of the station being 2,800 amperes at 500 volts. These engines were fitted with Joy's valve gear, controlled by a small centrifugal governor through the medium of a hydraulic valve.

Dynamos were very carefully insulated from earth, in some cases by half an inch of sulphur under the rails, and in all cases

by wood under the bed-plate, and where direct-coupled the coupling was insulated. This precaution is necessary where overhead wires are used, on account of lightning, to prevent a side flash between coils and framework. When a flash does pass by the machine, the damage is caused by the current of the machine following up the flash. The "magnetic blow-out" and "air-"blast" arresters are being supplanted by Wurt's water tank arrester, in which there is no spark gap. The well-known action of lightning in choosing to flash from coils to frame, instead of through magnet and armature coils to earth, on account of self-induction in the latter, is utilised in preventing its reaching the machine at all. Coils are placed in the line circuit—a sufficient number being in multiple to carry the current—and from these at intervals connections are tapped to carbon rods dipping into water in a tank. Lightning is checked by the induction of the coils, and discharges by the rods and water to earth. By the use of running water the normal loss from generators is reduced to a very small amount; and by using a small branch from the city water mains, with overflow pipe for this purpose, the additional advantage is gained of a good earth. Mr. Wilkinson

I found that a good deal of power was tapped off the 500-volt tramway circuits for supplying private motors. On the Cleveland Electric Railway Company's system there was 350 H.P. taken off for this purpose, the motors varying in size from one-eighth to 25 H.P. The tariff charged was 20s. per month per H.P. for 3 H.P. and over, or at the rate of 4d. per H.P.-hour; the H.P. being averaged by a portable meter kept on the circuit for a given time.

Improvements have been made in the design of street car motors, their attachment to car trucks, and in decreasing their weight for a given output. Through the courtesy of the General Electric Company I am able to give a few particulars of their latest type of 25-H.P. motor, known as the "G.E. 800 motor." This name is stated to be given to it on account of the drawbar pull exerted by the motor being 800 lbs. on ordinary street tracks, with 33-inch car wheels, the usual single reduction gear, and rated current.

Mr. Wilkinson.

The dead weight has been reduced to 1,450 lbs., or 730 lbs. below the former standard type of the same power, viz., the W.P. 50 (waterproof motor). Next to reducing the weight of the motor *per se* is the requirement of reducing dead weight on the axles and distributing it over the car. By the usual end suspension about half the weight is carried by the axle, and half by a cross-bar resting on springs; but by a new arrangement with side-bar suspension (Fig. 19), the whole of the weight is taken off the

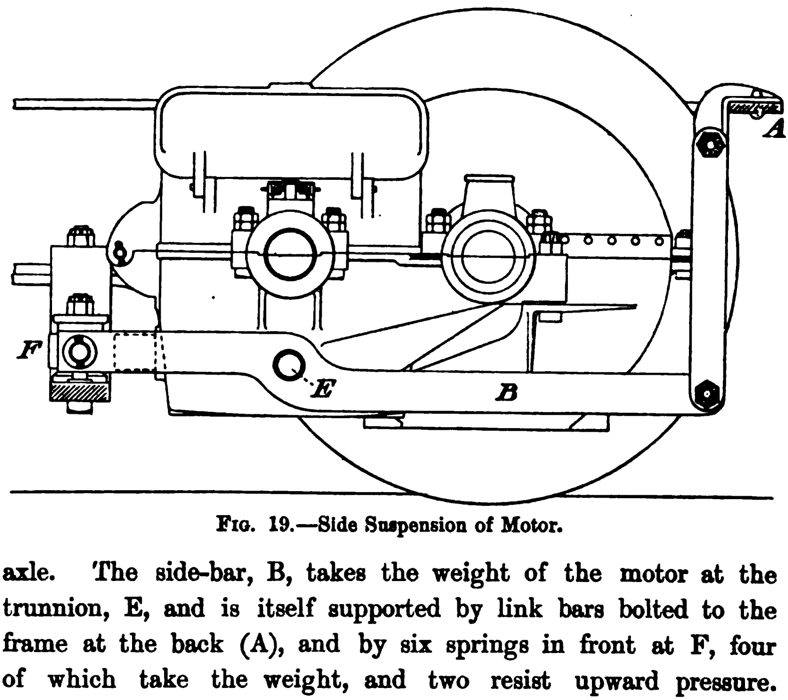

Fig. 19.—Side Suspension of Motor.

axle. The side-bar, B, takes the weight of the motor at the trunnion, E, and is itself supported by link bars bolted to the frame at the back (A), and by six springs in front at F, four of which take the weight, and two resist upward pressure. The wear and tear of the track is by these devices considerably reduced, and the running of the cars improved. The motor is enclosed in a cast-iron frame, in two parts hinged together, the same forming the field. There are two field coils, one in the upper and the other in the lower portion of the field; and, as these are wound to give similar poles, two additional consequent poles are formed between them, making a four-pole machine. The armature is cross-connected, so that only one pair of brushes is used; and these, with the upper field coil and

armature leads, are fixed inside the upper half-frame and swing back with it. The iron of the field is of course to earth, and therefore special care is necessary to insulate the field coils; but the chance of a fault is minimised by coupling the coils to the earth return, in which case they can only vary by a few volts from the potential of the frame itself. The axle gear, which runs in an oil chamber, is arranged for a speed reduction of 4·78. Mr. Wilkinson.

The latest type of Westinghouse motor for street cars is built in a cast-iron horizontal frame, on which are hinged the upper and lower field magnets, so that the armature can be got at from above or below. There are four field poles, with as many coils. The armatures are drum-wound, each coil being wound on a former of the size of a quarter the circumference of the core, then taped, and slipped into its place between the teeth of the core. The wires composing the coil are laid so as to form a flat strip, which goes in edgewise between the teeth and lies flat at the ends of the drum, so economising space. The whole is then covered with waterproof material.

There are various types of "controllers," or combination switches, for putting the two motors on a car in series and parallel. The switch handle has from five to ten notches, giving different grades of speed. The first, or starting, position puts the motors in series through resistances; the succeeding steps reduce the resistances, shunt one motor out of circuit, and finally put both in parallel. There is also a side lever operating a cylinder of contacts for reversing the motors. I tried the experiment on one of these controllers of making the motors act as an electrical brake. Getting them first up to full speed, the controller was put back to starting position, current switched off, motors reversed, and then put in parallel again. The slight difference in excitation between the motors then caused one to act as a generator and drive the other, making a very powerful and quick-acting brake. A single switch might be employed which would effect these changes, and so prove an important aid to the mechanical brake in an emergency.

In Philadelphia I found very few streets with overhead wires, and learnt that an active policy had been pursued by the City

Mr. Wilkinson.

Electrical Bureau towards the placing of all electric wires underground. One overhead trolley line was in operation, but the feeder cables were all in underground cement-lined conduits. Mr. D. R. Walker, chief of the Electrical Bureau, informed me that he, in company with the director of the Department of Public Safety, had examined into the systems of electric traction in other cities, with the view of employing the most suitable for the city of Philadelphia. He referred me to his report, which summed up as follows:—

"The overhead system or electric propulsion of street cars is, "in my opinion, better fitted for small towns or villages, or to "connect the same, or for the suburbs of a city such as our own; "but when it comes to introduce electricity as a motive power in "the heart of a large city, the circuits conveying the power for "the same can, and should, be placed beneath the surface of the "street. It has been effectually proven a success in Chicago, and "is now being introduced to a large extent in Washington, D.C.; "and any new privileges asked for in this direction should be "granted only on condition that all the wires used for such a "purpose should be placed underground. The only difference "between the overhead and underground systems is in the matter "of cost, which is but a secondary question when the safety and "comfort of our people, and maintaining the beauties of our "thoroughfares, are concerned. Again, a more reliable service "can be maintained underground than overhead, as it would be "free from interruptions caused by fire, falling of wires, or the "action of the elements. The franchises so granted are im-"mensely valuable, and while they are being issued the interests "of the city should be taken into consideration, and provision "made underground for its electrical systems and for the lighting "of its highways."

I may mention incidentally that the city authorities use, or own and rent to private companies, about 25 miles out of the 150 miles of underground conduit laid. I refer here to conduits constructed for the reception of electric cables and feeders, not for tram-car propulsion. The wires owned by the city are for telegraph and telephonic communication from the City Hall to fire and police

stations and street call boxes, of which there is a most complete system, and for the electric lighting of the streets. The city contracts with lighting companies to supply lamps and current only, posts and cables being erected and laid by the city. I was very much impressed with this imposing and beautiful city, and with the system of control exercised in the interest of the citizens over all electrical undertakings by the Electrical Bureau. Mr. Wilkinson.

Of the 12,000 miles of tramway in the United States and Canada, about 7,200 miles are operated by electricity, and 3,500 miles by horses. In conclusion, I need only remark how well adapted electric traction is to the wants of the people. Following the ordinary highways, where business is done and people congregate and travel to and fro, tramways afford at once a means of locomotion that is readiest to hand with least trouble to the traveller. For short distances, people will not go out of their way to get on the railway, or climb steep staircases to elevated roads, provided that the street tram-cars travel at a reasonable speed, with minimum delay. For the latter desideratum a modification of the American practice in cities of not stopping between "blocks" might be adopted, while for a reasonable speed we must look to other means of propulsion than horses. The cable system is very suitable in certain localities, such, for instance, as on straight and hilly roads, but the wear and tear of cable is enormous on curves. Steam is unsightly and obnoxious. Electricity affords at once rapid and noiseless travel, quick control, with small wear and tear, and the current can simultaneously be utilised for heating and lighting the cars. As a means of travel, I have not experienced in the States anything so pleasant as their well-lighted and fast-moving electric street cars; and I cherish the hope that ere long this public boon may be extensively put into action along the streets and lanes of our own country.

ABSTRACTS.

E. KOLBEN—ON THE QUESTION OF THE BEST FREQUENCY FOR ALTERNATE-CURRENT WORKING.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 6, *p.* 77.)

In considering this question of periodicity, all those parts of the system which are affected by the change must be taken into consideration—the generators, the motors, the transformers, as well as the cable system. The following phenomena, all depending on the frequency, must therefore form the subject of more detailed investigation:—

1. The dependence on the frequency of the hysteresis and eddy-current losses, which in their turn affect efficiency, heating, and cost of generators, motors, and transformers.
2. Increase of resistance, self-induction, and capacity of the mains with increasing frequency.
3. The influence of frequency on the parallel running of generators, and the working of motors.

In connection with 1, the author gives curves for charcoal iron 0·5 mm. thick, showing the hysteresis and eddy-current losses in watts per c.c. as functions of the induction density at frequencies varying from 10 to 500. Now the effective area of iron, S, in an alternator, motor, or transformer with a primary winding of N turns and a pressure E volts is known from the formula,

$$S = \frac{\sqrt{2} \,.\, E \,.\, 10^8}{2 \pi n \,.\, B \,.\, N},$$

where n is the frequency. This formula shows that the area of iron diminishes directly with the frequency and the induction density. The curves show that, since the induction density does not need to be reduced in the same proportion as the rise in the frequency, raising the frequency diminishes the area of the iron, thus decreasing the weight of iron and copper in the machine. Thus the machine is cheaper at the higher frequency, or has a higher efficiency. Naturally there is a limit to this, brought about by the increase of the heating with diminution of radiating surface. Therefore for small machinery having a relatively great surface a high frequency is desirable, and where each feeder is supplied by one machine, and every consumer is on his own transformer, as in America is very generally the case, a higher frequency should be used than in cases where large

dynamos are run in parallel and transformer sub-stations are in use. In the latter case there is no advantage in raising the frequency above 60; since the efficiency is not raised, and but little is saved in weight and cost of machinery.

2. The chief grounds for the adoption of low frequency lie in phenomena occurring in the cables—namely, the "skin effect" in large secondary conductors, and the self-induction and capacity effects. The first of these increases with the square of the frequency, and shows itself as drop in the mains in addition to that produced by the ohmic resistance. A curve is given showing the percentage increase of resistance as a function of diameter at various frequencies, which shows, among other things, that at a frequency of 140 $\sim$ cables of under half a square inch section have an added drop of 25 per cent. due to skin effect. The only remedy is to use strip or concentrically laminated cables.

The effect of capacity and self-induction is to raise the resistance, R, to the value,

$$R_1 = \sqrt{R^2 + \left(\frac{1}{2\pi n C} - 2\pi n L\right)^2},$$

called the "impedance," and depends on the distance between the conductor and its return, with the diameter of the conductor and the frequency. In overhead conductors this may be a very serious factor. With underground cables, however, the capacity may neutralise the self-induction, namely, when

$$\frac{10^6}{2\pi n C_1} = 2\pi n L;$$

and, as in most cases C and L are fixed by the conditions of the problem, the frequency should be chosen so as to make the above equation as nearly as possible true.

The effect of capacity in overhead working is often over-estimated. In some experiments conducted at Œrlikon on a line 46 kilometres long, 10 metres above the ground, of 0·25 microfarad capacity, the loss due to the charging current of 1·65 amperes was less than 1 per cent. of the output that could be carried by the wire with 10 per cent. loss of pressure, and the current was about 10 per cent. of the normal load current.

Such effects as the increase of the transformation ratio of transformers and the rise of pressure at the end of the line can be corrected by proper design of the transformers, so long as the capacity current does not seriously load the transformers and line.

3. The author refuses to theoretically discuss parallel working, as this depends largely on the type of machine used, and the frequency is not the sole factor There are stations on the Continent where with a frequency of 40 $\sim$ greater difficulty is experienced than in England with 100 $\sim$, or, even in exceptional cases, in America, with 140 $\sim$.

It may be noted that for design of motors the lower frequencies are better, as they permit a reduction of the number of poles. At 130 $\sim$ a motor would require from 10 to 20 poles, where at 50 $\sim$ it only requires 4 to 8. The light load current increases directly with the number of poles, and also t[illegible] current. The author therefore holds that in general 50 to 60 $\sim$ [illegible] frequency.

W. KUNZ—ON THE RELATION OF MAGNETIC HYSTERESIS TO TEMPERATURE.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 14, *p.* 194)

The author has already published in 1892 a short notice of the fact that hysteresis diminishes with increasing temperature, and the following results have been obtained from a long series of observations of this phenomenon. Four kinds of iron, two of steel, and one of nickel have been the subject of investigation. Special difficulties occurred in maintaining the wire samples at the high temperature for the required length of time, and in the measurement of these temperatures, and therefore the methods are more particularly described.

Measurement of Temperature.

Thermo-electric junctions were used, consisting of a platinum wire twisted for about 1·5 cm. of length round a wire of platinum containing 10 per cent. of rhodium. Two such couples were used, whose free ends were brought well insulated to a mercury switch, by means of which each couple could be connected to a Deprez-d'Arsonval galvanometer having about 200 ohms resistance. The temperature of the junctions at switch and galvanometer was always the same—about 20° C. The calibration of these couples up to 300° C. was done by an accurate mercury thermometer, plunged with one couple into oil, which was warmed up in large beakers surrounded with asbestos and kept well stirred. The galvanometer deflections corresponding to the temperatures from 40° to 300° were noted. From 300° upwards the calibration was done by utilising the known fusing points of certain substances melted by a gas furnace: the junction was placed in the molten material, the flame lowered, and the deflection noted when solidification began. Each couple was separately calibrated—the outside junctions being kept at a constant temperature by immersion in petroleum at 20° C.

The substances used and temperature measured, or assumed from Börnstein-Landolt's tables, were as follows:—

Substance Warmed or Melted.	Temperature or Melting Point.	Galvanometer Deflection.
	Deg.	
Oil	40	16·0
„	73	27·2
„	104	38·0
„	140	50·8
„	200	77·6
„	300	125·4
$K\,Cl\,O_3$	359	155·6
Pb Cl	498	244·4
I K	634	330·2
K Cl	734	393·6
Na Cl	772	417·8
$Na_2\,SO_4$ ...	861	474·2

Method of Heating.

Ledeboer has already used the method adopted—namely, winding an insulated platinum wire round the test wire, and heating it by passing a current through. The iron wire was contained in a porcelain cylinder having a suitable opening to take the thermo-couple, and round this cylinder was wound (non-inductively) the platinum wire. The insulation between the couple and the platinum was tested before each observation. This platinum coil was surrounded by layers of asbestos, among which the wires of the thermo couple were led out. The tube thus formed was placed inside a glass tube and accurately centred by suitable packing. This tube was placed again in another glass tube with asbestos distance pieces. A current of hydrogen passing through the inner tube protected the wires from oxidation. To protect the magnetising coil against the high temperatures, a hollow tube of pure copper was placed between, and a stream of water kept passing through it, and this had to be insulated by asbestos from the glass tubes to prevent their breaking. Observation showed that no heat passed through this jacket. The two couples always agreed in their indications, thus showing that the wire was evenly heated.

The Magnetic Observations.

As indicated above, the test wire was a long straight piece; its condition was observed by magnetometer, by the "single pole" method. The magnetising coil is placed vertically in the direction east and west from the magnetometer, and the top end of the magnetised wire is on a level with the instrument. The alteration in the position of the pole due to differences in induction density affect the distance between magnetometer and wire so little as to be negligible. The vertical component of the earth's field must be taken into account. In magnetising, the cycle was always performed a few times, until the curve became regular. Then a series of observations at varying temperature of a certain cycle was taken, generally with maximum B = 3,590 (about), until at the high temperature (830° C. or so) the magnetism disappeared. Then another cycle after cooling. Suitable arrangements were made for compensating for the effect of the magnetising coil itself on the magnetometer, and for demagnetising by reversals of a gradually diminishing current.

The strength of field in the middle of the solenoid is calculated from the well-known formula,

$$H = \frac{4\pi}{10} \frac{NC}{l},$$

where N = number of turns, C = the current in C.G.S. units, and l = the length of the solenoid; and the induction was calculated from the magnetometer deflection by means of the known value of the horizontal component of the earth's field.

Results.

The following tables are for a maximum induction density of 3,590, and are the mean of four series :—

Material.	Temperature.	Hysteresis Loss. Ergs.	Material.	Temperature.	Hysteresis Loss. Ergs.
	Deg.			Deg.	
German annealed charcoal iron	20	2,350	Swedish iron	20	2,690
	290	1,600		270	2,080
	470	1,204		460	1,550
	656	710		650	905
	728	550		742	825
	836	316		812	712
	20	2,107		20	Indefinite
Soft wrought iron	20	3,420	Puddled iron	20	3,100
	284	2,480		275	2,270
	468	1,750		460	1,730
	656	821		560	1,810
	744	800		656	979
	20	900		744	777
				20	2,090

These values show when plotted as curves that the equation, $L = a - b\,t$, where L is the hysteresis loss and t the temperature, and a and b constants, expresses fairly the law.

Material.	Temp.	Hyst. Loss in Ergs.	Material.	Temp.	Hyst. Loss in Ergs.
	Deg.			Deg.	
Hard patent steel	20	11,540	Patent cast steel	20	9,660
	309	11,580		309	9,860
	526	6,040		468	4,950
	660	2,200		560	1,985
	790	1,180		640	1,614
	20	5,230		744	1,048
				20	4,670

These two kinds of steel had for ordinary temperatures cycles in shape like a rhombus, altering in shape about 300°, even increasing in area, and between this and 470° changing in form to that of an ordinary iron curve and decreasing greatly in area. The character of the steel is lost after heating, as shown by the final observations, and it becomes also quite soft. There is no simple relation between hysteresis loss and temperature.

Cycles for Higher Values of Induction Density.

The following tables relate to charcoal iron:—

B.	Temp.	Loss.	B.	Temp.	Loss.
	Deg.			Deg.	
7,200	20	8,900	14,400	20	21.020
	270	6,690		270	14,840
	468	4,660		470	9,900
	570	3,340		570	7,550
	668	2,270		—	—
	744	2,168		—	—

For higher temperatures than 570, B = 14,400 could not be reached.

These results show that the above law also holds good, generally speaking, for higher values of induction density.

The corresponding results for steel show that the characteristics described for the lower values of induction density hold also for the higher. In all the above cases a new wire was taken for each series of observations. When an iron wire was subjected to repeated cycles of temperature and magnetisation the hysteresis losses decreased up to the fourth cycle of temperature, and then became uniform; the results of each temperature cycle being expressible as a straight line, but of different inclination. The steel wire has the first temperature cycle as already described, and the remainder behave like the soft iron.

In the case of nickel, subjected to a cycle of maximum B = 3,590, it was found that the hysteresis fell with the increase of temperature at first rapidly, and afterwards increasingly slowly: it fell from 11,420 ergs at 20° to 4,700 ergs at 288°.

One of the most important results is the fact that repeated cycles of magnetism at a high temperature reduce the hysteresis loss in iron very considerably, and it would appear that this is also the result of one cycle at a very high temperature.

— PASSAVANT—CONTRIBUTIONS FROM THE EXPERIENCE OF THE BERLIN ELECTRICITY WORKS.

(*Elektrotechnishe Zeitschrift*, 1894, *No.* 16, *p.* 230.)

In the first portion of this paper, a summary of the results of the working of the two systems for localising and signalling faults on the mains of the Berlin company is given. The principle of these systems is roughly as follows:— The first—that of Herr Agthe—utilises the pilot wires of the two outer mains of the three-wire system to signal the occurrence of a disturbance, and this is effected by connecting each to the pole of the dynamo opposite to that connected to the main with which they are run by means of a lead wire in the junction box, and in the station passing them round a relay. When the pilot wire and the main core cease to be insulated from one another, a current passes which rings the relay bell,

while the fuse in the junction box is blown. The position of the fault is indicated by the feeder on which the disturbance takes place.

In Dr. Kallmann's system, the differences of potential set up in the earth by a leakage current are employed to actuate the relay. The middle pilot wire is earthed at as many points as possible, and connected through a relay at the station again to earth. An earth contact on the main alters the potential of the earth in its vicinity, and the relay joined to the wire affected has a current through it which gives the alarm.

During the nine months in which they have been in working order, the relays have given 14 alarms, due to the following causes:—Three faults in house connections, six leaks due to water in the junction boxes, and five faults on the mains themselves. All cases where the pilot wire alone leaked are not included. The Agthe relays were the ones to give most of the alarms.

The causes of the failures were as follow:—In the house connections the faults are nearly always due to damp, and can be removed by special attention to this point. Water in the junction boxes is much more serious. The electrolysis which takes place sometimes destroys the box completely, and the affair must be taken in hand quite early, before the water accumulates to a serious extent. This is done by baring the wire connecting the pilot wire screws, passing it through an ebonite tube with open ends, and laying it on the bottom of the box. A small quantity of water short-circuits the pilot wire to earth, and the relay rings until insulation is restored. Of the five faults signalled on the mains themselves, three were due to blows with a pick, and two to failure of the cable itself. The author considers that the signalling apparatus is well worth its cost, and is, in fact, indispensable.

Leaving this question, the author records the progress of power supply in Berlin. There are 358 motors, with 1,200 H.P. on the mains, and over 100 H.P. more are in contemplation. In 1892-93 the power sold for motors was 238,000 kilowatt-hours, and in the first eight months of the year 1893-94 the total has reached 376,000 B.T.U. This large consumption is due to the low price, which was fixed at 3d. in 1891, and is now reduced to 2½d. The number of hours a day run by each H.P. connected has increased from 1·25 in 1892 to 1·8 now. Thus the motors are being used for longer hours than at first.

A. KOEPSEL—APPARATUS FOR THE DETERMINATION OF THE MAGNETIC QUALITIES OF IRON IN ABSOLUTE MEASUREMENT.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 15, *p.* 214.)

The principle of this apparatus is as follows:—The magnetic circuit is similar to that of a dynamo. The test piece forms the yoke, passing through the single magnetising coil, and fitting by long joints into massive iron limbs, forming the return. This return has a circular opening with a core, like the poles and armature core of a dynamo, and in the air space thus formed a coil, carrying a current, is pivoted. This carries a pointer, whose deflection is a measure of the induction in the air space.

It is found under these conditions that the true curve of the iron can be obtained by shearing the curve obtained in a certain way. Curves of various kinds of iron are given, as obtained by the machine, and the methods of calibration are fully described.

P. LENARD—ON THE MAGNETIC DEFLECTION OF CATHODE RAYS.

(*Wiedemann's Annalen, Vol.* 52, *No.* 5, *p.* 23.)

Cathode rays are deflected by a magnet. This deflection is not always the same in a field of given strength; it increases (in the ordinary vacuum tube) with increasing pressure of gas. It has generally been concluded that this is due to the lower speed of the "radiant matter;" but if, as the author thinks he has proved, the rays are ethereal phenomena, this cannot be the reason. The author finds now that conditions which must have the greatest influence on the speed of radiant atoms have no effect on the deflection by a magnet.

The author produces his cathode rays in a tube separated from that in which the deflection is effected, just as in his other experiments, and the rays pass out through an aluminium window into the outer tube where the deflection takes place; the two tubes are exhausted separately.

If the conditions of production of the rays are kept constant, and the pressure in the outer tube is lowered, it is found that in a range of pressure from 33 mm. to 0·021 mm. no alteration in deflection is produced, and this range is 100 times as great as any which has hitherto been under observation; higher pressures could not be used owing to the turbidity of the medium, which renders the spot produced by the cathode ray ill defined. But when the pressure in the outer tube is kept constant, and varied in the producing tube, the deflection varies, increasing with increased pressure.

Keeping the conditions of production again constant, it was found that, whether hydrogen, oxygen, or carbon dioxide were the gas in the outer tube, the deflection was the same.

The deflection was independent of the intensity of the rays. If an additional aluminium screen twice the thickness of the window were interposed in the path of the rays, and the rays were thus much weakened, the deflection remained the same. This experiment was performed in air at 0·024 mm., in hydrogen at 20 mm., and in oxygen at 0·03 mm. pressure. The attempt to alter the deflection of the rays by any alteration whatever in the observing space was completely unsuccessful.

The author's earlier researches showed that in a turbid or semi-turbid medium the rays produced at lower pressures are less diffused than those produced at higher pressures. He now finds that the more diffusible rays are more deflected by a given field. It is probable that every kind of cathode ray has its own special amount of deflection which it retains under all circumstances, and cathode rays would probably best be characterised by this quality. A peculiar deformation of the phosphorescent spots was noticed when deflected. When undeflected the spot has a core surrounded by a lighter penumbra, the relative amount of this penumbra

depending on the turbidity of the medium. In very turbid media there is no core; in very highly exhausted tubes there is no penumbra. It was found that in every case the penumbra was more deflected than the core. This shows that at a given pressure in the producing tube rays of a certain degree of diffusibility preponderate and form the core; but there are also produced rays of greater diffusibility which form the penumbra, and which are, as has been stated, also more deflected by the magnet. It is found in some cases that where no penumbra occurs in the undeflected spot, owing to the rarity of the medium in the observing space, the same phenomenon of part of the rays being more deflected than others occurs. These phenomena form a sort of magnetic spectrum of the cathode rays; as in the case of light with rays of different refrangibility, so here the rays of different diffusibility and deflectibility are separated in space from one another.

The author says, in conclusion, that, according to Hertz's experiments, the action is not one of the magnetism on the rays themselves, but on the medium which they traverse. But the medium has been shown by the author to be the ether itself, for the curvature was found to be completely independent of the nature and density of any ponderable matter present, and was seen in the highest possible vacuum. Cathode rays therefore give evidence of an alteration of the condition of the ether between the magnet poles, as is demanded by the theory of the action at a distance which they produce.

F. MYLIUS and O. FROMM—THE FORMATION OF FLOATING METAL SHEETS BY ELECTROLYSIS.

(*Wiedemann's Annalen, Vol.* 51, *No.* 4, *p.* 593.)

The authors' attention was called to the phenomenon which they here investigate by the accidental observation of a formation of floating sheets of metal during the electrolysis of a concentrated solution of zinc sulphate.

If a flat vessel be provided in which is laid a plate of zinc about 5 square cm. in area as an anode; if this be covered with about 2 cm. depth of a 50 per cent. solution of zinc sulphate, and the upper surface be touched with a platinum wire about 0·2 mm. thick, serving as cathode, so that the solution rises round it by capillary attraction; and if, finally, these electrodes be joined up to a Gülcher thermopile of about 3 volts pressure, there begins to be formed round the cathode wire a shining zinc plate which floats on the liquid, and gradually increases the area of its circular surface. In a few minutes it attains an area of several square centimetres. This plate itself acts as cathode, and as it grows the strength of current rises up to 0·1 ampere. Its thickness increases very little, as the current passes chiefly through the edge of the plate, but in a somewhat irregular manner. After a certain time the plate formed is not unlike a leaf of vegetable formation, with distinct veining. The upper surface of this film is dry, and shines metallically; the under side is also white, but less brilliant.

The anode may also be arranged at the side of the cathode, or it may take the form of a wire. A cylinder of zinc plate is very suitable, the cathode being at its centre. In this way plates of zinc can be produced by a current of 10

amperes having a diameter of 10 cm. and a thickness of 0·2 mm. The experiment is not always successful, especially if the solution of zinc sulphate is very clean, and the cathode wire purified from organic matter by heating to red heat. On the other hand, a little oil on the surface works very favourably for the success of the experiment. Under these conditions the film is formed between the oil and the zinc sulphate. The effect of oil, especially of oil of turpentine, is so remarkable that the formation appears almost to be caused by some oily foreign substance on the surface of the solution. If the glass vessel contain chloroform or some similar substance of great density, on which the zinc sulphate floats, and the cathode touch the solution through the chloroform from below, the film is formed underneath the zinc sulphate in the inverse manner.

The zinc film follows the capillary raising or sinking of the surface, and has the property of growing round any obstacle which may be in the way. It is therefore possible to completely enclose drops of foreign matter which float in the solution with a film of zinc by touching them with a cathode wire insulated nearly to the end. Such drops may consist of chloroform and turpentine mixed together.

The experiment will not succeed in a vacuum, nor in oxygen, hydrogen, or nitrogen; its occurrence appears to depend on the presence of free oxygen, and the oils which help the formation of the film all contain more or less oxygen in an active form.

The experiments with zinc were followed by others with silver. On a concentrated solution—about 20 per cent.—of silver nitrate containing an excess of ammonia, shining films of silver are produced under the same conditions as described above for zinc; but these films are more brittle than those obtained with zinc sulphate. In this case, also, oily impurities on the surface assist the formation of the films. The necessity for the presence of oxygen was only certainly observed with somewhat weak solutions.

Films could also be produced in solutions of copper, cadmium, cobalt, iron, and antimony; on the other hand, the less easily oxidisable metals, such as nickel, gold, and platinum, appeared not to be suited to the formation of films. In every case in which the formation took place the conditions appeared to be the presence of an impurity not capable of solution in water, and free oxygen capable of producing a chemical reaction. The thickness of the oil film is of no particular importance.

Finally, the observation was made that conducting oxides and sulphides—as, for instance, the lower oxides of silver and of cadmium, peroxide of lead, and so on—could spread themselves from suitable solutions in the form of films.

ANON.—THE ELECTRIC RACK-RAILWAY ON MONT SALÈVE.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 21, *p.* 289.)

This is an interesting addition to the extensive system of tramways already existing in Geneva and the neighbourhood. The ascent of Mont Salève is a well-known trip from Geneva, and the mountain is a limestone chain having three

more or less defined summits, to one of which—the Grand Salève, about 4,500 feet above the Lake of Geneva—the rack-railway ascends. The railway ends at Treize, Arbres, about 500 feet below the summit, whence fine views are obtained of Mont Blanc, the valleys of the Arve and the Rhone, the Lake of Geneva, and the Jura. The line is constructed under a concession from the departmental authorities of Savoy, and is entirely on French territory. This railway is the first instance of electric traction applied to gradients of 25 per cent.; its gauge is 1 m. It starts from two points, Etrembières and Veyrier, both about 1,300 feet above the sea, and connected with Geneva by existing steam railways, 9 and 6 kilometres long respectively. The Etrembières branch ascends the steep slopes of the Petit Salève and has free views over the lake; the Veyrier branch goes through a romantic gully between the Petit and the Grand Salève, and joins above this the other branch. At this point, about 2,000 feet above the sea, the railway winds up the slopes of the Mont Salève partly through woods, but mostly on bare spots. It has three branches, each about two miles long, with the Monnetier Station as a centre. The total length is 9·1 kilometres, of which about a third is on very sharp curves. The whole ascent from Etrembières to Treize Arbres is about 2,250 feet, the steepest ascents being gradients of 20 to 25 per cent. The permanent way consists of a rail-bed 11 feet 6 inches wide—special precautions being taken against slipping—carrying Vignoles rails of 33 lbs. weight per metre, bolted to steel sleepers. These rails are 8·4 cm. high. The central rail is of the Abt form, and is single on gradients of under 10 per cent., and double on steeper slopes. On the Abt system each of these has two racks, with the teeth in opposite phase, so that on the steep gradients the train has four points of support. The rails are all designed for a maximum weight of car of 8 tons, but the actual weight is 14 tons. The teeth are 5 cm. deep, and 7 cm. long at the root, calculated to stand 2·03 tons, and have to stand a pressure of 3·6 tons actually, but this is divided among two or four teeth, owing to the double rack, so that there is a certain factor of safety; but the author considers that, seeing that everything depends on these teeth, the safety factor is not enough. The fixing on the rack is precisely similar to that on the Brienz-Rothhorn Railway. Each rack is 1·8 metres long, and has a weight of 28 lbs. per metre. The length of line having single racks is 3·8 kilometres, and the rest, 5·3 kilometres, has double sets. The crossings and junctions are of the well-known Abt type now in universal use.

The conductor is also a Vignoles rail, inverted, and carried on suitable supports at the side of the way, being about 1 foot 8 inches from the nearest rail. The flat foot used for the contact slider is 35 cm. above the sleepers, and 26·6 cm. above the rails. The rail is carried on double-bell-shaped porcelain insulators, and the connection is made from rail to rail by a copper fish-plate bolted and sweated on. The excessive changes of temperature in some portions made a flexible copper connection necessary. This work complete cost 40,000 M. (£2,000) per kilometre, of which 16,000 are for the ordinary rails and permanent way, 16,000 for the rack, and 8,000 for the conductor.

Electrical Station.

This is placed at Arthaz, some 1,350 feet above the sea, where the river

Arve makes a great bend; it is dammed up by a dam 80 m. long, and delivers at a minimum 20 cubic metres per second, with a fall of about 3 metres, being equivalent to about 800 H.P., which is turned into 560 H.P. of mechanical energy by turbines of 70 per cent. efficiency. Trouble has been experienced from sand and stones in the water, which even a strong wire netting in front of each turbine chamber has not been enough to check in flood-time. The tail race is a tunnel 5 metres wide and 150 metres in length. The present motive power is delivered by two Jonval turbines, with space for a third; the diameter of these is 10 feet, and they rotate 45 to 60 revolutions per minute. The three deliver 250 H.P. A smaller turbine of 28 H.P. drives the exciter, and is automatically regulated for constant speed, the others being regulated by hand. The dynamos are the largest yet constructed for direct current of the multipolar Thury form, and are direct-driven from the vertical turbine shafts. At 180 revolutions they would give 1,000 H.P. At 45 revolutions they give 275 amperes at 600 volts, or 165 kilowatts, instead of their normal output, so that naturally the plant is rather expensive; but their use has its advantages in simplicity and solidity. The dynamos have 12 poles, and the fields are series-wound. The commutators are 6 feet in diameter, and are on the turbine shafts; the current being taken off by 36 carbon brushes held in ebonite brush-holders, with spring feed. Each dynamo weighs 9 tons—about 88 lbs. per kilowatt for normal output. The exciter is a separate machine run by a belt, and giving 90 amperes at 100 volts, exciting both machines. The regulation of the whole system is automatically performed by alteration of the field of this exciter. The carbon brushes completely suppress sparking at the commutator. On the switch-board are all necessary switch gear and instruments, regulators, &c., together with suitable lightning arresters. These, however, did not avert the burning out on one occasion of 32 sections out of 451 on the armature of one of the dynamos. This is probably due, says the author, to the fact that when the spark passes the dynamo is short-circuited through the lightning arrester.

The Transmission.

The power is delivered to the Monnetier Station about a mile away through copper cables, with a drop of 12 per cent., the usual maximum being 450 amperes. These cables are carried overhead on porcelain insulators, and are 60 cm. from one another horizontally, to avoid short-circuit from breakage.

At Monnetier the cables are connected to the conductor and the rails respectively, the loss here being 15 per cent. On each section only two cars run on the steep gradients at once, and the maximum current is about 230 amperes.

Motors.

Each car has two four-polar motors, series-wound Thury machines. They give 30 H.P. at 600 revolutions per minute, but can give 50 H.P. at 1,200 for a short time without damage. The maximum speed on the steepest slopes is 6 kilometres, say 4 miles, an hour. The gear wheels, about 2 feet in diameter, make 50 revolutions per minute, the reduction being 12 : 1, through double gear.

The motors are in series, as one will not start the car, chiefly owing to the enormous weight of the gearing. The motors weigh 2·6 tons, the gearing being 3·4 tons, the dead weight being 75 per cent. of the total. There are about 165 lbs. per kilowatt to be raised. Hand screw brakes are provided.

At first no other connection than earth was provided between the rails, but such disturbances arose in the neighbouring telegraph and telephone wires that the authorities insisted on a complete metallic return, and the rails are now joined by cables.

The total costs amounted to £92,000, or about £10,000 per kilometre.

The losses are 48 per cent., of which 10 per cent. are in the generators, 12 per cent. in the transmission and conducting rail, and 26 per cent. in the motors and gear. The average gradient is 12·7 per cent.; the average speed 8 kilometres per hour, or 2·5 yards per second.

Unlike the other mountain railways, this line is intended to work all the year round, when not prevented by snow or by the freezing of the turbines. In summer there are 30 up and down trips per diem, and in winter 15. The maximum traffic would be 1,100 persons a day, the trains being sometimes one and sometimes two cars together. Goods are carried also, and water for the restaurant on the top. The ascent takes an hour, the descent 40 minutes, and the fare from Geneva and back is 4·60 marks, say 4s. 6d. There is little doubt, concludes the author, that all mountain railways in future will be electrical. The great saving lies in the use of water power, in spite of its great initial cost.

G. CLAUDE—QUESTIONS RELATING TO THE WORKING OF CENTRAL STATIONS.

(*La Lumière Électrique, Vol.* 51, *No.* 15, *p.* 51.)

I.—Considerations with respect to Lighting.

Since the popularity of electric lighting, gas companies have found it necessary to introduce more economical and efficient gas-burners; the only inducement to retain customers being to reduce their gas bill. As incandescent lamps will give considerably more light when worked above the normal pressure, so will gas-burners when worked at a higher temperature of combustion. In both cases, however, the life is diminished, which is not a serious item so long as the cost of the lamps or burners is small as compared to the cost of energy.

In the author's opinion, the best way of competing with gas is to over-run incandescent lamps—a point which was, however, open to some controversy. Experiments were made on French lamps of 10 normal candle-power: these were run at 16 candle-power, absorbing energy at the rate of 2·5 watts per candle. These lamps lasted 200 hours before the light fell to 20 per cent. below the normal candle-power. The cost of energy during the period of 200 hours for a 16-candle-power lamp would be 8 francs for eight kilowatt-hours. The total cost, including the price of the lamp, would be 10 francs. To run this lamp for 800 hours would therefore cost 40 francs, against 50 francs for a normally worked lamp, thus effect-

ing a saving of 20 per cent, when lamps are run at the rate of 2·5 watts per candle.

The ordinary type of gas-burner consumes 175 litres of gas per hour, which, at the rate of 30 francs per cubic metre, corresponds to 0·0525 franc per burner per hour; and in the case of over-run lamps this price comes down to 0·05 franc.

With a 16-C.P. Auer burner, the cost of the lamp-hour is about 0·032 franc.

II.—Considerations relating to the Day Load in Stations.

A station limiting its supply for the purpose of electric lighting only, has its plant running idle, on the average, for about four-fifths of the day. Great efforts are therefore made to run the plant at its highest possible efficiency.

It is not sufficient to merely increase the demand for energy, since by so doing the tendency is to increase the load at certain hours without improving the load-factor. It is necessary to obtain a demand for energy at other times than during lighting hours, and numerous plans have been suggested for arriving at this end.

Accumulators might be charged during daylight hours and discharged at night concurrently with the dynamos. This system is, however, open to some objections. In the first place, the capital outlay is great; with respect to output, they occupy a large space; and the upkeep is expensive. Such high efficiencies as 85 and 86 per cent., as have lately been obtained in Germany, are not habitual in France, a fair limit being about 75 per cent.

Again, although the use of accumulators might prove a great advantage in winter, it would not be so in summer, when the demand is only about half as great. The effect of day load to a gas company is different, on account of the accumulators (gasometers), for it is not of much importance when a heavy load comes on. If, however, a heavy day load were habitual with a gas company, it would be advisable to increase the size of the plant, but not so in the case of electric lighting. Notwithstanding this, gas companies in Paris offer every inducement, with a reduction in price, for the supply of gas for the production of motive power.

Whether the day load be supplied for motive power, electrolysis, or electric heating, some special device must be employed for differentiating between the day and night load.

The simplest method is to use two meters on the two distinct circuits used for lighting and for motive power. This system, however, lends itself readily to fraud, as lamps can easily be placed on the second circuit.

The best method is to have a minimum tariff for certain hours of the day, and a maximum between certain hours of the night, and the use of either two meters or one meter with two counters, either of which could be made to gear with the meter at specified times.

C. LIMB—A DIRECT METHOD FOR THE ABSOLUTE MEASUREMENT OF ELECTRO-MOTIVE FORCES.

(*Les Comptes Rendus, Vol.* 118, *No.* 22, *p.* 1198.)

A general method for measuring an electro-motive force in C.G.S. units is to balance against the fall of potential produced by a known current passing through

a known resistance. If the fall of potential, R I, balances the unknown electro-motive force, then E = R I.

Three years ago the author proposed to simplify the method by directly comparing the unknown electro-motive force to an induced electro-motive force, in which case the latter would be calculated. For this purpose the author employs a permanent magnet rotating in a coil. If the bobbin carries n turns per centimetre, and the electro-motive force is sinusoidal, it has the following maximum value:—

$$E_{max.} = 4 \pi n M w,$$

where M is the magnetic moment of the magnet, and w its angular velocity.

The bobbin consists of a thick tube of ebonite about 70 cm. long and 10 cm. external diameter, wound with one layer of carefully insulated wire 0·3 mm. diameter.

The number of turns, n, was found to be 22·0499 per centimetre. The magnet consists of 65 bars, 4 mm. square by 6 cm. to 8 cm. long, of Allevard steel, made up in five rows of 13 each, and separated from each other by strips of aluminium 1 mm. thick. The magnets are contained in an aluminium case, which is mounted on a spindle to allow of its being rotated. At one end of the spindle is fixed a pulley, and at the other a commutator. Contact is made by means of two German silver brushes at the moment when the E.M.F. is a maximum. The magnets are rotated by means of a small electro-motor. The magnetic moment, M, was measured by Gauss's method; the couple, M H, being balanced against a torsional couple. The value of M was found to be 3,250 C.G.S. units.

The motor employed had a nominal output of 800 watts. On the spindle on one side are fixed a pulley, and a fly-wheel weighing 40 kg.; and on the other side a commutator with five brushes, the latter being employed for determining the constancy of rotation by Lippmann's sensitive method. Small variations in speed are compensated for by means of a string brake acting on the spindle.

The angular velocity was measured by taking the simultaneous records of a seconds pendulum and of each revolution of the magnets, on a recording cylinder. The speed varied from 6 to 13 revolutions per minute. Having measured n, M, and w, the E.M.F., $E_{max.}$, can be determined, making the necessary corrections for the effect due to the ends of the bobbin, and also for the variation of M with temperature.

The electro-motive force obtained during tests varied from 0·3 to 0·7 volts.

A direct comparison between $E_{max.}$ and the E.M.F. of a standard cell could be made, but an increased speed would be necessary. The author found it more convenient to compare the two E.M.F.'s by means of a potentiometer. The equality of the potential was determined by a Lippmann capillary electrometer.

ANON.—THE PREPARATION OF CERTAIN MINERAL COLOURS BY ELECTROLYSIS.

(*La Lumière Électrique, Vol.* 52, *No.* 21, *p.* 376.)

Scheele Green.—An electric current is caused to pass through an 8 per cent. solution of sulphate of soda, by means of two copper electrodes immersed in the

solution. The tank containing the solution must be heated by means of spiral steam pipes. A bag of arsenious acid suspended in the warm solution will dissolve and react on the soluble copper salt formed by the action of the current.

According to the *Revue de Chimie Industrielle*, the electrolysed sulphate of soda yields sulphuric acid and oxygen, which oxidises the copper.

The oxide of copper dissolves in the acid, while the soda combines with the arsenious acid at the negative pole to form arsenite of soda. The reaction of the arsenite on the sulphate yields a precipitate known as Scheele's Green. In order that the process should be continuous it is only necessary to renew the copper plates from time to time, and to refill the bags with arsenious acid.

Mitis Green.—By replacing the arsenious acid in the above process by arsenic acid, arsenate of copper will be obtained, and which is known as Mitis green. As arsenic acid is very soluble, it is slowly added in solution to the bath.

For 100 grammes of copper, 100 grammes of arsenious acid are necessary to produce Scheele green, and 125 grammes of arsenic acid for Mitis Green.

One H.P. dissolves 150 grammes of copper per hour, and precipitates from 200 to 225 grammes of green.

Cadmium Yellow is obtained by electrolysing a solution of chloride of sodium, and using cadmium electrodes. A current of sulphuric acid must be passed through the bath during the process of electrolysis.

Sulphate of cadmium of various tones can be obtained by this method.

Vermilion.—In a wooden bath about 1 metre in diameter and 2 metres in height are placed two circular plates, on the top of which is a layer of mercury about 1 centimetre thick. These plates constitute the positive pole of a dynamo. The bottom of the tank is fitted with a plate of steel-plated copper, and forms the negative pole. The solution contains 8 per cent. of nitrate of ammonia and 8 per cent. of nitrate of soda. A perforated spiral tube is placed in the bath to allow of a current of sulphuretted hydrogen to pass. Red sulphide of mercury is thus obtained.

An attempt has been made to dispense with the currents of gas by using the following bath:—

Water	100 litres.
Nitrate of ammonia	4 kilogrammes.
Nitrate of soda	4 ,,
Sulphide of sodium	4 ,,
Sulphur	4 ,,

Vermilion of very fine quality can be obtained by this process, provided the quantity of mercury and its equivalent of sulphur be maintained.

Japanese Red.—This colour is a lake of oxide of lead coloured with eosine. It can be economically prepared by electrolysing a 10 per cent. solution of acetate of soda with two lead electrodes.

The eosine must be run into the bath, and the oxide of lead which is formed will absorb the colouring matter, and can be finally separated by decantation. By varying the strength of the eosine solution, varying depths of colour can be obtained. The eosine can be substituted by other colours, such as rodamine. Also, the lead may be replaced by zinc, in which case oxide of zinc would be formed.

The acetate of soda can be replaced by nitrate of soda, or a mixture of nitrate of soda and ammonia.

ANON.—THE MANUFACTURE OF CHROME AND ITS ALLOYS BY ELECTROLYSIS.

(*La Lumière Électrique, Vol.* 52, *No.* 21, *p.* 377.)

A bath containing 10 to 15 grammes of bisulphate of potash, 100 grammes of chrome alum, and 100 grammes of water is electrolysed: at the negative pole a deposit of chrome will be precipitated. The bath must only be maintained by the addition of chrome alum alone, or by a mixture of alum and bisulphate of potash, also adding a small quantity of chlorate of potash.

P. CLÉMENTITCH DE ENGELMEYER—ON THE MEASURE OF DIFFERENCE OF PHASE.

(*La Lumière Électrique, Vol.* 52, *No.* 21, *p.* 360.)

The author first refers to a series of articles by M. Hess, and wishes to complete this study by describing some experiments lately made at Messrs. Fein's works at Stuttgart. He first recalls experiments made by M. von Ettingshausen and M. Puluj.

M. von Ettingshausen made his experiments in 1876, when there existed no precise notion about self induction. He directed his researches to the retardation of induced currents produced by the magnetism of iron cores introduced into bobbins. Lissajou's mirrors were mounted on two tuning forks having the same period of vibration: one of them placed on the primary circuit acted as a mercury contact-maker, while the vibrations of the second one were maintained electrically by an electro-magnet excited by the secondary current. The tuning fork was strongly magnetised, in order to give the same number of vibrations as the current, and not double the number.

M. Puluj in 1893 worked with vibrators which were not magnetised, and consequently obtained double the frequency.

M. von Ettingshausen mentions the necessity of knowing, apart from the position of the ellipse on the screen, the direction of the two component vibrations, as well as the sense of the spot of light, in order to determine the difference of phase produced by the introduction of the iron core. It is, however, very difficult to determine this sense, as the velocity is so great.

M. von Ettingshausen suggested that a stroboscopic method should be employed. A third tuning fork, with a slightly larger period than the two others, causes the beam of light to be interrupted before it reaches the two other forks. The nearer the period of vibration of the third fork to the two others, the more easily can the sense of the spot of light be determined. The resultant ellipse is represented by

oblique co-ordinates corresponding to the component vibrations, the latter being almost at right angles to one another. The difference of phase, D, measured along the axis of time (period = τ) is determined, after measurements on the screen, by the formula,

$$\pm \sin \frac{2\pi D}{\tau} = \frac{ab}{PQ} = \frac{cd}{PR} = \pm \sin \phi.$$

M. Puluj employed exactly the same process, but represented the effect due to self-induction by the following formula:—

$$\text{Tang. } \phi = \frac{2\pi}{\tau} \frac{L}{R};$$

L being the coefficient of self-induction, and R the ohmic resistance.

These methods are, however, subject to some errors. M. Ettingshausen has had errors of 1 per cent. between results; and M. Puluj has found differences of 1·1 per cent. when taking the mean of results, and on comparing these with the results of calculation the errors amounted to 2·9 per cent. These are no doubt due to the difficulties in making measurements on the screen, and also to the want of symmetry of the vibrators with respect to the beam of light.

To eliminate these errors the author devised a new combination of Lissajon's mirrors.

Two mirrors, A and B, are so pivoted that their planes are parallel to one another when at rest. A beam of light is made to pass through a small hole situated on the axis of vibration, the mirror A; the light then falls on the mirror B, which is only silvered at a small spot on its own axis of vibration, the remaining part being left transparent. The light is reflected back on to A, and is then sent back through the transparent part of B on to a screen.

Apart from the symmetry of the figure resulting from this combination, there is a great advantage in being able to work with different degrees of sensitiveness without altering any parts of the apparatus.

The author states that by this method it is possible to work with the minimum deflections, with any desired degree of sensitiveness.

Phasemeter with Rotating Mirror for measuring the difference of phase between two currents at the moment when either of them passes through zero.—A small mirror is made to rotate uniformly round an axis, making a certain angle with the plane of the mirror, and synchronously with one of the currents; another mirror, B, vibrates synchronously with the other current. A scale is so arranged that its readings can be read on the mirror B.

To set the instrument before taking a reading, the two mirrors must be actuated by the same alternating current, in order to ensure synchronism of their movements. The bent scale must then be moved in order that its zero can be read, which will appear at rest owing to the strobosopic effect, since the light only falls on the scale once in every period. When there exists a difference in phase between them, the eye sees the different divisions of the scale pass successively with the variation of phase. For any given constant difference of phase the eye sees a certain division A on the scale, and the angle which the arc of the scale subtends, is a measure of the difference of phase between the two currents.

P. ROBERT—A LIGHTNING FLASH IN AN ELECTRIC CENTRAL STATION.

(*La Lumière Électrique, Vol.* 52, *No.* 19, *p.* 261.)

The author draws attention to a case where a central station itself was struck by lightning, during a storm which took place over Paris, on the 26th of last April. The station in question is situated in one of the suburbs of Paris, and transmits power at high tension by means of overhead lines to other stations in Paris itself. This high-tension current works motors driving low-tension dynamos.

During the storm, the station was struck, and one of the units broke down in a few seconds. The machine in question was a Marcel-Deprez motor of 100 H.P., working two Edison dynamos coupled to each end of the spindle by Raffard couplings. All the electro-motors in the station were insulated from earth. The foundation bolts were cemented into the foundation, and were insulated from the bed plates of the motors by means of ebonite sleeves. The bed-plates themselves were insulated from earth by means of fibre and paraffined oak. The insulation resistance of the whole machine to earth was generally found to be from 5 to 6 megohms. Between the armature winding and the frame of the machine the insulation resistance was double these values.

The high-tension overhead line, eight miles long, had an insulation of 7 to 8 megohms to earth. The lightning flash struck the armature of the motor, and appeared to come from the roof of the station. The discharge passed through the shaft of the motor to one of the Edison dynamos, and thence to the switch-board, where a bright flash took place, followed by a loud detonation, and finally found its way to earth through the low-tension network.

On the high-tension line all fuses and lightning arresters remained intact, although one of the machines at the generating station was damaged at the same instant.

The insulating materials of the motor armature which was struck were completely carbonised, and some of the bars were fused to the gun-metal spiders supporting the discs. On removing the bearings to get the armatures out, it was noticed that at two points on the shaft some of the gun metal from the bearing had fused on to the shaft. The air gaps had been the seat of a violent discharge, and traces of copper were found on the polar faces of the magnets.

It is therefore very essential that every precaution should be taken, and that the station itself should be protected from lightning as well as the line, or otherwise the consequences may prove most fatal.

ANON.—TRANSMISSION OF POWER FROM LAUFFEN TO FRANKFORT.

(*La Lumière Électrique, Vol.* 52, *No.* 19, *p.* 273.)

The report of tests made on the above transmission has lately been published under the supervision of Professor H.-F. Weber. As the time for making tests

was limited, the Commission found it necessary to study the following questions, which were considered the most important:—

1. What was the power developed by the turbine at Lauffen at a given angular velocity and with a given fall?
2. What relation has the energy supplied to the tertiary circuit at Frankfort to the energy transmitted during the same time by the turbine to the dynamo?
3. What was the efficiency of the dynamo, of the primary transformer, and of the secondary transformer, at the particular load, during the tests for the efficiency of the whole transmission?
4. What loss took place in the high-tension line, 170 kilometres long? Are the losses due to ohmic resistance only, or are there other losses?

Concerning the first question, it was found, after taking a mean of six tests, that the turbine gave 232 H.P. with 3·75 m. effective fall and a speed of 160 r.p.m.

The determinations of the efficiency of the transmission were made in the following manner:—

After loading up the secondary transformer at Frankfort by means of lamps placed in the three tertiary circuits, a telegraphic message was sent to Lauffen, and the next series of tests were made five or ten minutes later; the message was answered, and the operators at Lauffen brought the dynamo to the normal speed of 150 revolutions.

One series of tests lasted about 10 minutes, and necessitated taking the following readings:—

1. The load of the turbine and the level of the water—up and down stream.
2. The strength of current in the three primary circuits.
3. The primary voltages between the terminals of the machine and the neutral line placed to earth.
4. The exciting current of the dynamo.
5. The speed of the dynamo.

The observations at Frankfort consisted in determining the power in the three tertiary lines and in the fourth neutral line. The three wattmeters employed for this purpose were brought back to zero three times per minute, and the sense of the couple was changed every minute, so that every wattmeter yielded 31 readings for each series of tests. From these 31 readings 10 mean readings were taken. The report shows a remarkable uniformity between the tertiary currents, of which the source was 170 kilometres distant.

The power supplied by the second transformer was, on the average, 114 H.P.; the mean tertiary pressure was 64·3 volts, the mean strength of the tertiary current was 440 amperes, and the mean efficiency 74·4 per cent. It was found that atmospheric conditions had extremely little influence on the efficiency.

The normal power of the turbine was 300 H.P. During the tests the maximum output was 154·4 H.P. The full-load efficiency of the dynamo at Lauffen was 95·4 per cent.

The tests on the transformers yielded the following results:—

The efficiency of the transformer of the Société Génerale d'Électricité at 100

kilowatts was 96 per cent. The maximum efficiency, when the iron and copper losses were equal, was found to be 96·1 per cent. The Œrlikon transformer yielded almost the same results.

The report generalises the results as follows:—

1. In the Lauffen-Frankfort installation for the transmission of power by alternating currents at 7,500 to 8,500 volts through a bare copper overhead line carried on insulators, there was available in the tertiary circuits at Frankfort 68·5 per cent. at lightest load, and 75·2 per cent. at heaviest load, of the power supplied by the turbine at Lauffen to the generating dynamo.
2. It is considered that all the losses in the system are due to Joule effects.
3. Theoretical considerations have shown that the influence of capacity on the line is so small for currents of 30 to 50 periods per second as to be negligible.
4. The behaviour of the circuit, with air insulation, and when carried on porcelain, is as reliable with alternating currents at 7,500 to 8,500 volts as with low-tension currents.

ANON.—A NEW DYNAMO MACHINE BY TH. MARCHER.

(*La Lumière Électrique, Vol.* 52, *No.* 19, *p.* 280.)

It is an easy matter to determine experimentally what influence the diameter of a coil has on the magnetism of its iron core. It will be found that the outside turns of a bobbin have not the same effect as the inner ones. An iron core was first wound with wire 2 mm. diameter, and next with 0·8 mm. wire, and the same current was sent through; these coils having the same number of turns. In the first case the external diameter of the bobbin was 41 mm., and in the second case 30 mm., which allowed the core to be brought closer to the poles of the machine. The magnetic flux was increased 44 per cent.—considerably more than was due to the shortening of the iron circuit. In the first case no doubt a certain number of lines closed round the wires and never reached the iron. The loss in the bobbin in the second case was increased from 1 to 4·45, on account of its resistance. A short bobbin with a large depth of winding is not only magnetically bad, but also requires more copper than a longer bobbin, keeping the length of the magnetic circuit constant.

Numerous experiments have been made on hollow cores. M. de Waltenhofen has compared solid iron cores with hollow cylindrical cores of the same section. He found that for small degrees of magnetisation the hollow core was better, but beyond this the best results were to be obtained with a solid core. He attributes this to the fact that at first the resistance of the iron cylinder is very low as compared to the air resistance, and that the surface is greater in the case of the hollow cylinder than with the solid iron core, but as the magnetisation is increased this advantage is diminished.

The author considers that the best core to use is a solid cylinder, and gives curves of magnetisation obtained with a square section and round section.

This form of two concentric cylinders has been applied to the magnetic circuit of dynamos built by the firm of Pœschman & Co., of Dresden. A solid magnet core is fixed to the bed of the machine. Above this is placed the opposite pole-piece, connected to the base by an outer cylinder. Two holes are made in the latter to allow of the ends of the armature to pass through. By this method magnetic leakage is reduced to a minimum.

The upper pole-piece is so designed that the armature shall receive an upward pull, and consequently relieve the weight on the bearings.

M. Puluj has made experiments on a 200-lamp machine, and found an efficiency of 91·5 per cent. at half load, being equivalent to an efficiency of 93 per cent. at full load. These machines work practically sparkless, and occupy a very small space.

P. BOUCHEROT—TRANSMISSION OF POWER AT MESSRS. MENIER'S FACTORY AT NOISIEL.

(*La Lumière Électrique, Vol.* 52, *No.* 20, *p.* 301.)

There are still some objections raised against non-synchronous alternating motors. Amongst the criticisms there are perhaps two which may in some cases be justifiable. In the first case the initial torque is relatively small with a constant current. This is of little importance in cases where the torque is small at first, and increases with the speed, as with a ventilating fan, for instance; but when it is necessary to start machines offering a constant resistance and large inertia the motor will require a proportionally large starting current, and special starting devices have then to be used in order to prevent too large a strain being placed on the generators. These devices are almost as simple as those used for starting continuous-current shunt motors. The second objection raised against alternating-current motors—which in many cases need not be considered—is the impossibility of varying the speed of the machine without introducing resistances into the armature circuit. This is the main reason why such motors have not yet been employed for traction work; but, apart from this case, it is usual to require a constant speed for motors. The author describes one of the first power stations in France, in which motors with rotating magnetic fields are used.

MM. Menier own a large estate at Noisiel (Seine and Marne) on which water power is available. This estate has several villages, a private railway, a farm, and the well-known chocolate factory. The latter is built on the banks of the river, and is worked by three turbines of about 200 H.P. each.

The electrical installation in question is used for working agricultural appliances, and for lighting a farm at a distance of 2 kilometres from the factory. The installation has been working for a year, and the results have proved most satisfactory. The height of the fall varies from 1 to 4 metres, depending on the time of the year. The whole of the electrical apparatus was made by the firm of Weber & Richard, and designed by Mr. C. E. L. Brown.

The alternator works on the two-phase system, has eight poles, and is capable of giving 75 horse-power at 600 revolutions, and equivalent to a frequency of

40 complete alternations per second. Each half of the armature gives 150 volts at 165 amperes. The weight of the whole machine is 2,700 kilogrammes. The eight field coils are fixed radially to an outside ring of cast iron. The armature consists of a hollow drum of laminated iron discs, on the outside surface of which are fixed flat coils, and those of one phase being placed above those of the other phase. Each circuit consists of eight coils coupled in two series parallels. The ends of each circuit are connected to suitable collecting rings. Lubrication for the bearings is effected by means of rings revolving in oil boxes.

The exciter is separately driven, and is capable of giving 90 volts and 15 amperes at 1,800 revolutions per minute, and is used for exciting a Bovet magnetic coupling as well as the alternator. This coupling requires about 50 volts and 1·5 amperes when the alternator is working at full load. A careful test was made to obtain the efficiency of this type of alternator, and the system adopted was as follows:—The alternator was first run at its normal speed, and so excited as to give the normal voltage at full load; readings being also taken of the exciting current, in order to determine what power was wasted in the field. Next, the losses from friction and windage, hysteresis, and Foucault currents were measured; and from these losses, added to those in the armature and field, can be determined the efficiency of the machine. This method, although not correct in the case of a single-phase alternator, where the armature reactions produce Foucault currents in the polar masses, is, on the contrary, as correct for a two-phase alternator as it is for a continuous-current machine. The two phases of such an alternator when equally loaded produce a rotating magnetic field with respect to the armature, and having an equal velocity, but opposite in sign, to that of the armature, is consequently fixed in space like the armature field of an ordinary continuous-current machine. In an ordinary single-phase alternator there is superimposed on this fixed field a rotating field having a velocity double of that of the armature, producing extra losses, and consequently prohibiting the use of the above method for determining the efficiency. It is for the above reasons that it is possible to obtain with any given carcass a greater output with a two-phase than with a single-phase winding. For instance, the above alternator could only give an output of 40,000 watts instead of 50,000 watts if it had a single-phase winding.

For determining the internal losses, the armature was rotated by means of a small continuous-current motor the losses in which had been carefully predetermined. A first test was made with the field not excited, to ascertain what losses were due to friction and windage, and a second series of tests were then made with the field excited to give normal voltage and speed. Tests were also made at different speeds, in order to separate the losses due to hysteresis (or losses proportional to speed) from those due to Foucault and internal currents (or losses proportional to the square of the speed).

The results obtained are plotted in curves, and an abstract of the tests is given in the following table :—

—	At Full Load.	At Half Load.	At Tenth Load.
Loss in the armature	1,700	420	20
Loss in the field	1,370	1,260	1,160
Friction	540	540	540
Hysteresis	390	380	370
Foucault and internal currents	1,550	1,500	1,460
Useful power	50,000	25,000	5,000
Total power	55,560	29,090	8,550
Efficiency	90 %	86 %	58 %

The switch-board is of polished marble, and contains a double-pole switch and fuses, an ammeter, and a hot-wire voltmeter; also, for the exciter, a voltmeter, an ammeter, and a field rheostat. There are no instruments or regulating appliances on the high-tension side. The step-up transformers are each of 15,000 watts capacity, making in all 30,000 watts. The surplus power of the alternator to be used for future extensions. These transformers raise the pressure from 150 to 2,700 volts, and are placed in a special non-oxidisible insulating oil. The windings were previously well heated in the oil, in order to drive out all moisture.

The following table gives the losses and efficiencies of these transformers:—

—	At Full Load.	At Half Load.	At Tenth Load.
Loss in the primary	150	45	6
Loss in the secondary	150	40	2
Iron losses	325	325	325
Useful power	15,000	7,500	1,500
Total power	15,625	7,910	1,833
Efficiency	96 %	95 %	82 %

The high-tension line on leaving the transformers runs underground for 500 metres, and consists of a lead-covered steel-armoured cable, consisting of four strands each 7 mm.^{2} section, insulated with rubber. This cable was manufactured at MM. Menier's factory at Grenelle. The line is protected by double-pole lightning arresters placed in the same box as the double-pole switches and fuses. These lightning arresters consist of zinc discs separated by mica. The centre disc is connected to earth, and the outer ones to the line. The boxes containing the switches are so designed that they cannot be opened while the alternators are excited. After the underground section of 500 metres, the line runs overhead for about 1 kilometre, and consists of a phospor-bronze wire 3 mm. diameter.

The total resistance of each circuit is from 4·5 to 5 ohms. The maximum loss is about 2 per cent. The efficiency of the line then becomes 98 per cent. at full load, 99 per cent. at half load, and 99·8 per cent. at tenth load. The step-down transformers are similar to the step-up transformers described above.

This installation has in use at present two biphase motors of 15 to 20 H.P., and one single-phase motor of 1½ H.P.

One of the large motors drives a thrashing machine, and the other works on to a countershafting from which other agricultural appliances are driven. The small 1½-H.P. motor is used for a hay lift. Special precautions have been taken to box in all collectors and brushes where sparking is liable to take place, in order to minimise all fire risks during the process of thrashing.

The starting torque of these motors is very large, perhaps greater than at full load. The starting device consists of coils of high self-induction placed at the moment of starting across the terminals of each circuit, the motor circuits being connected to only a small number of the turns. When full speed is attained these coils are cut out.

A motor with closed armature is absolutely equivalent, when at rest, to a transformer with a short-circuited secondary. Placing such a machine in circuit is then equivalent to short-circuiting it at that moment. For this reason it would be necessary to place in each circuit a resistance or self-induction, in order that the current taken from the generator should not be abnormal. But, on the other hand, a strong current at low pressure is necessary in each circuit, in order that the motor should start at full load. A self-induction coil or a resistance would then, in themselves, not be sufficient to prevent this rush of current. A transformer might be used, with its fine coil connected to line, and thick coil to one of the motor circuits; but, unfortunately, by this method a high enough speed could not be obtained to allow of the transformer to be disconnected, on account of the low voltage at the transformer terminals, and, consequently, the weak field in the motor.

The combined method described above allows the motor to take a large current on starting without loading the generator, and also to obtain a high enough speed in order that the starting device may be promptly disconnected. The line current necessary for starting the motors depends on the machinery they are driving, but it varies from 40 to 50 per cent. below or above the full-load current.

Particulars and efficiencies of the system when working under different conditions are given in the following list:—

1. When the Transformers are Fully Loaded and the Two Large Motors are Working Alone.

Useful power at the motor pulleys ...	13,000 + 13,000 =	26,000 watts.
Losses in the motors	2,000 + 2,000 =	4,000 ,,
Losses in the low-tension lines... ...	120 + 280 =	400 ,,
Losses in the step-down transformers...	... ...	1,200 ,,
Losses in the high-tension line... ...	... ...	600 ,,
Losses in the step-up transformers ...	... ...	1,250 ,,
Losses in the alternator ...	700 + 1,300 + 2,450 =	4,450 ,,
Total power at the pulley of the alternator	... ...	37,900 ,,
Total efficiency of transmission ...	... ...	69 per cent.

2. For a Mean Load on Three Motors.

Useful power at the motor pulleys	10,000 + 10,000 + 1,000 =	21,000	watts.
Losses in the motors		2,550	,,
Losses in the low-tension line	65 + 155 + 20 =	240	,,
Losses in the step-down transformers...		950	,,
Losses in the high-tension line...		350	,,
Losses in the step-up transformers		970	,,
Alternator losses	460 + 1,260 + 2,420 =	4,140	,,
Total power at the alternator pulley		30,200	,,
Total efficiency of transmission		69·5	per cent.

3. The Thrashing Machine Working Alone with an Average Load.

Power at the motor pulley		10,000	watts.
Loss in the motor		1,100	,,
Loss in the low-tension line		65	,,
Loss in the step-down transformers		685	,,
Loss in high-tension line		80	,,
Loss in step-up transformers		710	,,
Alternator losses	110 + 1,200 + 2,870 =	3,680	,,
Total power at the alternator pulley		16,320	,,
Total efficiency of transmission		61·3	per cent.

CLASSIFIED LIST OF ARTICLES

RELATING TO

ELECTRICITY AND MAGNETISM

Appearing in some of the principal Technical Journals during the Month of MAY, 1894.

S. denotes a series of articles. I. denotes fully illustrated.

ELECTRIC LIGHTING AND POWER.

W. DE FONVIELLE—Electricity at "Olympia."—*Lum. El.*, vol. 52, No. 19. p. 271

P. BOUCHEROT—Transmission of Power at Messrs. Menier's Factory at Noisiel —*Lum. El.*, vol. 52, No. 20, p. 301, No. 21, p. 369 (I.).

G. RICHARD—The Mechanical Applications of Electricity.—*Lum. El.*, vol. 52, No. 20, p. 315 (S. I.).

G. RICHARD—Arc Lamps.—*Lum. El.*, vol. 52, No. 21, p. 364 (S. I.).

F. UPPENBORN—Statistics of Central Stations.—*E. T. Z.*, 1894, No. 18, p. 255.

BEHN-ESCHENBURG—An Experiment on the Transmission of Power over 46 Km with Pressures of 33,000 Volts, made at Œrlikon.—*E. T. Z.*, 1894, No. 19, p. 261 (I.).

E. SCHULZ—Power Transmission by High-Pressure Direct Currents.—*E. T. Z.*, 1894, No. 20, p. 278.

O. GUSINDE—Comparative Statistics of Central Station Working in 1892–93.—*E. T. Z.*, No. 21, p. 285.

ELECTRIC TRACTION.

G. RICHARD—Electric Tram and Rail Ways.—*Lum. El.*, vol. 52, No. 10, p. 263 (S. I.).

J. H. VAIL—The Importance of Complete Metallic Circuits for Electric Railways —*E. T. Z.*, 1894, No. 18, p. 250.

MEYER and MÜTZEL—Telephonic Disturbances due to Electric Tramways.—*E. T. Z.*, 1894, No. 20, p. 273.

ANON.—The Electric Toothed-Wheel Railway on Mount Salève.—*E. T. Z.*, 1894, No. 21, p. 289 (I.).

DYNAMO AND MOTOR DESIGN.

E. J. BRUNSWICK—Domestic Electric Motors, and Generators of Low Output.—*Lum. El.*, vol. 52, No. 18, p. 208 (I.).

G. RICHARD—Details of Construction of Dynamo Machines.—*Lum. El.*, vol. 52 No. 18, p. 216 (I.).

MAGNETISM.

C. NEUMANN—On the Theory of Magnetism.—*Beibl.*, vol. 18, No. 5, p. 591.

L. MURS—On the Magnetism of Iron Rings whose Surface is only partly Covered by Two Symmetrically disposed Coils.—*Beibl.*, vol. 18, No. 5, p. 592.

J. DECHANT—On Magnetic Time Lag in Iron Cores caused by Periodically Changing Magnetising Forces.—*Ibid.*, p. 595.

P. SZYMÁNSKI—Experimental Introduction to the Theory of Magnetic Induction on the Basis of the Theory of Magnetic Lines of Force.—*Beibl.*, vol. 18, No. 5, p. 598.

INSTRUMENTS AND MEASUREMENTS.

A. RAPS—Apparatus for the Demonstration of Ampère's Experiments.—*Beibl.*, vol. 18, No. 5, p. 590.

C. LIMB—Method for the Direct Measurement of Electro-motive Forces.—*C. R.*, vol. 118, No. 22, p. 1198

ANON.—The Nielsen Meter.—*Lum. El.*, vol. 52, No. 18, p. 232 (I.).

ANON.—The Bormann System of Electric Signals to Moving Trains.—*Lum. El.*, vol. 52, No. 19, p. 275 (I.).

G. GUGLIELMO—The Absolute Electrometer, and Method of Measuring the Dielectric Constants of Liquids.—*Lum. El.*, vol. 52, No. 20, p. 336.

ANON.—The Elihu Thomson Lightning Arrester.—*Lum. El.*, vol. 52, No. 21, p. 378 (I.).

ANON.—Registering Compass for Ships.—*Ibid.*, p. 379 (I.).

L. KOHLFÜRST—Automatic Time-Giver of the Prussian State Railways, Berlin.—*E. T. Z.*, 1894, No. 18, p. 245 (I.).

M. KALLMANN—Regulating Apparatus for Central Stations.—*E. T. Z.*, 1894, No. 20, p. 274 (I.).

TELEGRAPHY AND TELEPHONY.

ANON.—Telegraphs and Telephones in Belgium, 1892.—*Jour. Tel.*, vol. 18, No. 5, p. 121.

ANON.—Telephonic Tariffs.—*Ibid.*, p. 138.

J. BOURDIN—Rational Organisation of a Central Telephonic Bureau.—*C. R.*, vol. 118, No. 22, p. 1226.

ANON.—Bimetallic Telephone Wires of Eckert.—*Lum. El.*, vol. 52, No. 18, p. 228 (I.).

Anon.—The Anizan-Mercadier Microphone.—*Lum. El.*, vol. 52, No. 20, p. 328 (I.).

Anon.—Telephonic Connection of Berlin-Tilsit-Memel.—*E. T. Z.*, 1894, No. 19 p. 267.

F. Uppenborn—Fuses for Protection of Telegraph and Telephonic Apparatus.—*Ibid.*, p. 271.

H Engelmann—Thunderstorm Alarm for Telephone Systems.—*E. T. Z.*, 1894, No. 22, p. 303.

Anon.—Telephonic Connection of Berlin and Vienna.—*Ibid.*, p. 304.

STATIC AND ATMOSPHERIC ELECTRICITY.

P. Lenard—On the Magnetic Deflection of Cathode Rays.—*W. A.*, vol. 52, No. 5, p. 23 (I.).

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O. GUSINDE—Remarks on the Electric Lighting Rules of the German Associated Insurance Companies.—*E. T Z.*, 1894, No 22, p 298

NOTICE.

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An Index, compiled by the late Librarian, to the first ten volumes of the Journal (years 1872–81), and an Index, compiled under the direction of the Secretary, to the second ten volumes (years 1882–91), can be had on application to the Secretary, or to Messrs. E. and F. N. Spon, 125, Strand, W.C. Price Two Shillings and Sixpence each.

JOURNAL

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Institution of Electrical Engineers.

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The Two Hundred and Sixty-seventh Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, November 8th, 1894—Mr. ALEXANDER SIEMENS, M. Inst. C.E., President, in the Chair.

The minutes of the Ordinary General Meeting of May 24th, 1894, were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

David Alexander Bremner.	George Edward Hartmans.
Henry A. Dando.	A. E. Kennelly.
George Vaughan Fowler.	Charles Henry Wordingham.

From the class of Students to that of Associates—

Frederic J. Warden-Stevens.

Donations to the Library were announced as having been received during the recess from the Agent-General for New South Wales; the American Society of Civil Engineers; the Astronomer

Royal; Messrs. Cassell & Co.; the Chief of the Electrical Bureau of the City of Philadelphia; Dr. A. C. Crehore; the Editor of *Electricity;* the India-Rubber, Gutta-Percha, and Telegraph Works Co.; the Minister of Italian Telegraphs; Messrs. Siemens Bros. & Co., Ltd.; Mr. F. C. Webb; Messrs. Whittaker & Co.; the Under Secretary, Post and Telegraph Department, Queensland; Sir David Salomons, Vice-President; Messrs. Bramwell & Harris, W. Perren Maycock, J. N. Shoolbred, and Herbert Laws Webb, Members; C. A. Stevenson, Associate and F. D. Latimer, Student; to all of whom the thanks of the meeting were unanimously accorded.

The following paper was then read:—

NOTES ON ELECTRIC TRAMWAYS IN THE UNITED STATES AND CANADA.

By H. D. Wilkinson, Member.

(Supplementary Paper.)

Mr. Wilkinson.

In the paper communicated to this Institution I have endeavoured to lay before you some notes on the working of electric tramways on the continent of America. I have not gone so much into descriptions of material and plant as into those questions which I heard constantly being discussed with reference to the return circuit of electric tramway systems and the marked electrolytic action in some cities on underground pipes and cables.

While the single-trolley system is almost entirely universal, I took pains to find out such details of the double-trolley system in Cincinnati, and the underground conduit in Chicago and Washington, as I judged would interest the members of this Institution, not only on account of their using an insulated return, but also on account of possible practical utility in their mode of working.

For the details of these systems I must refer you to the original paper; but, in order that the points put forward on the

various systems may be made clear, I have had some diagrams prepared which show the general scheme of each. Mr. Wilkinson.

Considering first the predominating single-trolley overhead system—the mileage of which to-day in the United States and Canada exceeds that of all the steam, cable, and horse traction systems put together by 50 per cent., and to which, owing to its exceedingly adaptable and flexible character, the enormous development of electric traction in those countries has been due—we have the current supplied to the cars through the medium of a bare copper wire stretched centrally over the rails of the track at a height of about 19 feet from the ground. The current is collected from this wire by means of a thin steel tube and trolley wheel mounted on the roof of the car, the wheel running on the under side of the wire, and being kept up to the same by springs on the tube. The current is conveyed by an insulated wire to the controlling and reversing switches and fuse to the motors, a lightning arrester also being in circuit.

The overhead trolley wire is divided into sections of one-quarter or half a mile in length, insulated from each other, and supplied with current from the power station by separate insulated feeders, as shown in Fig. 1 (Plate A).

As each section is independently supplied, it follows that the size of the trolley wire does not depend on the length of line, but simply on the length and average load per section, and is therefore uniform in size throughout, and generally about $\frac{1}{3}$ inch in diameter.

On this system the current passes from the electric motors to the iron frame of the car, and thence by the wheels to the rails and earth. As the earth presents an almost infinite mass compared with the rails, it was assumed in the first instance that a return of least resistance would be secured by well earthing the negative poles of the dynamos. The coal bill, however, stimulated inquiry into the losses in transmission of electric energy.

On many lines of 5 to 10 miles the voltage at the most distant section between trolley wire and rails was only 50 per cent. of that generated at the station.

Some improvement was made by sinking deeper earths into

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moist soil and connecting the same to more points on the rails. But at the best this was unreliable and variable, and it was noticed that improvement was more marked when attention was turned to the rails themselves as the best return conductor.

High-resistance fish-plate joints were bridged over by iron and then by copper wires, and the rails at their nearest point of approach to the power station were connected by overhead return cables to the dynamos, thus affording a reliable metallic return, while at the same time the earth formed part of the circuit.

Other diagrams on Plate A illustrate the stages of development in the return circuit; Stage 1 being that just described, viz., bonded rails and return cables.

In Stage 2, we have the rails connected at intervals to water and gas pipes; this step creating, from the traction companies' point of view, a most satisfactory rise of potential on the line, and improvement in speed of cars at the distant points on their system, but also raising the potential of the pipes above that of the earth, and bringing into existence electrolytic pitting and corrosion followed by leakage and danger, and producing, as the secretary of the gas company in Washington described to me, a feeling akin to sitting on the top of a volcano. The electrolytic consequences ensuing on this method of "helping out" the return circuit led to a reconsideration of the matter.

It was found impracticable to root out all such connections, or to provide such inspection as should prevent its recurrence; but the action was mitigated by clamping copper bands round the pipes at affected points, the same being connected to cables leading directly to the negative collecting bars in the power station.

All this pointed to the advantage of a metallic return, and led to the use of the supplementary wire shown in Stage 3. This consisted of a bare copper rod, wire, or cable, laid on the sleepers between the rails throughout their entire length, connected by twisted and soldered wires to the rails on each side of the fish-plates, and cross-connected to a similar wire in the adjoining track every 30 yards. But on all lines which I have seen being laid in this manner the wires have been uniform in section

throughout (about ⅜ in. diam. for the central wire, with smaller wires to bridge the rail joints), instead of increasing in section as they approach the power station in proportion to the increased volume of current. Unless proportioned to admit of constant density of current, I fail to see that this attains the desired end. Mr. Wilkinson.

The appreciation of this fact led to the adoption in Cleveland by Mr. Charles W. Wason of return feeders connected to the rails every 500 feet—shown in Stage 4. The feeders were increased in section and number as the lines neared the generating station, and added to from time to time to meet increased traffic.

Other engineers whom I met were considering the adoption of such return feeders on their lines, as a means of improving their efficiency of transmission.

Through all the stages thus far the idea has been retained that the negative poles of the dynamos must be connected directly to earth at the power station. Doubtless, if there are no return feeders and poor rail-bonds, or if the return feeders are of insufficient section to carry the current ousted from rails so bonded, a portion of the current will take to the earth and metallic bodies within it on its way back to the generators; but, although it will cost a little more, I think we can afford to dispense entirely with the alternative earth path, and should do without it. The safety of buried pipes and cables would thus be assured, and the efficiency of transmission increased.

It may be urged that the rails are perforce in contact with earth, and therefore the alternative earth path is always present. The answer to that is, Let the negative poles of the dynamos be connected to the rails direct by insulated cables, but not to earth at the station, and the current will then be kept within the rails and return feeders. The only chance for current to pass to earth would be as a shunt round bond joints of high resistance or insufficient conductivity; and should this occur, it will only cause electrolytic corrosion at such joints, and not on underground pipes and cables.

Having arrived at this point, I now divide the exclusively metallic return so obtained under two heads, viz., feeders and rails. If we put return feeders to every half-mile of rails, as we put

Mr. Wilkinson. them to every half-mile section of trolley wire, the bonds become of lesser importance: that is, firstly, they need only be of section sufficient to take the maximum current *per section;* and, secondly, they will be of uniform sectional area throughout. All the return current is then collected by the feeders, and returned to the generators direct. Each feeder collects or drains off the return current for a certain distance on each side of its point of attachment to the rails, as shown in Stage 5; and when current is collected in this manner at several centres along the route, it cannot all rush to one spot, near the power station, where the density is not only seriously increased, but voltage and power are wasted.

But if we do without return feeders altogether, then the current is returned entirely by the rails, and the bonds are of great importance.

Since the original paper was communicated, rail-bonding has been much improved, and I believe we can thoroughly rely upon these joints as permanent connections. Adequate area of contact with the rail, and that of a permanent character, are the main points.

I have taken exception to the supplementary wire; but it increased in section, say every quarter of a mile, as it approaches the power station, it would do nearly as well as insulated feeders, provided the connections from the rails to the generators were made at the nearest point to the power station by insulated cables. On lines where the route rounded curves or loops it would not do as well, because the current might find a short cut across corners if the earth favoured. By this method, also, current would be "bunched" at one point, instead of being collected and returned at intervals by feeders.

I now come to the double-trolley overhead system. (See also Plate A.)

In the original paper I have given an account of my visit to Cincinnati, Ohio, where this system is in operation. I went there to look into the system with an open mind and ascertain whether there were any adequate advantages to be gained for the use on one track of two overhead wires and two trolleys instead of one.

The idea and the principle were, of course, complete insulation from earth. Mr. Wilkinson.

I need not repeat here what I have already reported as having seen in Cincinnati, but I may summarise by saying that I found one of the trolley wires in connection with earth, although not in direct connection. I could light the lamps in a single-trolley car by changing the trolley wheel on to one of the double-trolley wires which ran over the same track. However, no direct path for the return current through the earth would be offered by one wire being earthed, because there was (as there must be with this system) a complete return circuit of insulated feeders from the sections of negative trolley wire to the generators, in a similar manner to that on the positive side.

In other words, the return circuit was a complete duplication of the outgoing circuit, and the dynamos delivered their current outwards by insulated feeders, and received it back by insulated feeders of equal capacity.

Any connection of either trolley wire to earth, therefore, could not cause a flow of current directly from the rails to the generators, since the latter were not in connection with earth *at the power station.*

That this fact was an advantage, in view of electrolytic troubles resulting from return currents through earth, I could not doubt; but, notwithstanding the mechanical and commercial success of the double trolley in this city, I could not but reflect that, if we are to have overhead wires at all, *one* is better than *two*, and there might be other ways of effecting the same object.

This led me to look at the single-trolley system again, and to ask myself the question, "Would not the same immunity from "return earth currents be secured if, instead of earthing the "generators and favouring an earth path, the return current "should be collected direct from the rails by insulated feeders in "communication with the negative side of the generators?" I am convinced that it would, and that the gaining of such immunity by insulated return feeders, connected at half-mile intervals to the rails on a single-trolley system, quite compensates for the extra cost.

Mr. Wilkinson. Thus I am led back to the same conditions as in Stage 5; and this conclusion strengthens the position of the single trolley, while, so far as any superior advantage is to be gained, it disposes of the double trolley.

At the same time, I am bound to admit that, notwithstanding the increased amount of overhead work, and the extra insulation required at points and crossings, no serious mechanical difficulty presents itself in the double trolley; and the Board of Affairs of that city have acknowledged its practicability and success in authorising considerable extensions.

To the gentlemen connected with both systems in Cincinnati, who courteously gave me opportunities of making observations on any part of their systems, and whose names I have mentioned in the original paper, I expressed at the time, after visiting the power stations and travelling over 10 miles in double- and single-trolley cars in the city and suburbs, my gratification in finding the double trolley work so well; but a somewhat over-zealous though well-meaning reporter put as one of the head lines of an article on my inquiry into that system, that "London will copy." I should be very sorry to disappoint that gentleman or his readers in their good wishes for our metropolis, but I have advanced points which I think show that simpler systems can be made equally advantageous.

In the three-wire system, of which I have prepared a diagram (see Plate A) of the outside circuit, two 500-volt generators are connected in series, the middle wire being to earth, and the free positive and negative terminals connected to the feeders radiating from the station. The single overhead trolley wire is used, divided as usual into sections insulated from one another, so that the outside line work is precisely the same as in the two-wire system. Instead, however, of these sections being all of positive potential, they are connected alternately to the positive and negative feeders. Thus only a small part of the total current used in propelling the cars returns by the rails or earth to the station, and that only when the load is not balanced on the different sections of opposite potential. For this reason, I heard that the system was to be tried in districts affected by pipe corrosion on

some of the great lines in Massachusetts, but with what result I have not heard. There is, however, a line in successful operation at Portland, Oregon, which I have not seen; but am pleased to say that the authors of the next paper, Mr. R. W. Blackwell and Mr. Philip Dawson, can give us details of the practical working of this system, gathered on the spot. Mr. Wilkinson.

I have also laid before you some notes on the conduit or slotted rail system, which has been working successfully for some time in Chicago, and Washington, D.C., as I judged that the members of this Institution should be put in possession of such information as could be obtained on the spot. To avoid repetition, I must refer you to the original paper for details of this system, but I have the drawings here for your reference.

In the conduit there are two rigid copper rods supported from above at intervals on insulating blocks and gun-metal clips. The rods were in the first instance stretched continuously, but were afterwards divided into sections, with sleeves and springs to take up for expansion. I went up and down the line on the cars, which worked smoothly and perfectly; and by entering a manhole got my head in the conduit, so that I could watch the running of the trolley wheels as the cars went by. The sparking was inappreciable, and the system worked perfectly.

The mechanical details at points and curves were well worked out.

I have seen other conduit systems on paper, and there are probably several that would work equally well if given so fair a trial as that in Washington; but I have not thought it worth while to bring any system before a body of practical men, capable of designing as good systems as any others at present on paper, without having seen it myself in actual successful work; and the system described has certainly gained public and administrative confidence, and I believe has sound commercial prospects of further expansion.

I was very pleased to see Messrs. Siemens's defence of the Buda-Pesth conduit line, which is both exhaustive and timely. Somehow or other, an impression has prevailed that a 1¼-inch slot is inseparable from an electric system; whereas the case at Buda-

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Pesth was that advantage was taken of the wheel flange slot already existing, and this was necessarily somewhat wide. There is no difficulty in making the slot ⅜ inch, and bedding the insulated wires of the collector in a ½-inch steel carrier.

The conduit and slot in the centre of the track, however, is the most satisfactory, as it is not subjected to any continuous wear from the travel of the cars.

Of the two systems of electric street tramways, the single trolley is most suitable for outlying districts, and the conduit for towns.

Although necessarily moving slower in town streets on account of the traffic, and therefore not showing all their good points, it must not be overlooked that electric cars have tractive power to tackle ascents of 1 in 10; and the running expenses per car mile are cheaper than by horses.

The approximate total cost of buildings, machinery, and rolling stock is the same in both the trolley and conduit systems, and amounts to from £1,200 to £1,500 per motor car. The overhead work and poles with single trolley costs about £2,300 per mile of double track, including permanent way, and the conduit system about £4,000 per mile of single track.

Cost of rolling stock and permanent way would, of course, be materially reduced for smaller gauges than 4 feet 8½ inches.

The feeders, both main and return, should be underground, at any rate within town limits, after which there is not much objection to their being carried on the same poles as the trolley wire.

With the extensive experience gained in this country in underground conductors, a good drawing-in system, with spare ducts for adding to the feeders as traffic increased, could be laid in a thoroughly reliable manner, and not cost very much more than special overhead poles. We should then have the overhead trolley system without the great mass of heavy insulated feeder cables on tall poles so disfiguring in American cities.

Let us bury our feeder cables and put up no span wires, and then all that is left is a set of light ornamental poles spaced 100 feet apart, with brackets supporting one single-trolley wire per

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track. Make them of lattice or ornamental scroll work, or make them of more massive ornamental cast iron, to receive in addition arc lamps for the lighting of the streets. But let us be assured that the overhead trolley is not so unsightly as many would have us imagine, and that it can be put up in an ornamental and unobtrusive manner.

In Philadelphia the insulated feeders are in underground conduits, together with bare copper strips as returns; but I am not aware whether the dynamos are insulated at the power station, or insulated return cables led to the nearest point on the line in the manner I have described.

The third rail system is not generally applicable to any lines, except where built in an exclusive route of its own. The use of storage batteries I have not touched upon. There have been trials in America, but less experience gained than in England and the Continent. If the cost of depreciation and renewal, which is out of all proportion to that of the transmission systems, could be materially reduced, the self-contained battery system would claim attention for town and city traffic. Data on recently worked lines on this system would be welcomed from members who have had experience of such lines.

American cars have no top seats, although the double-decked cars, as they are termed, are coming into use in a few places.

We are lovers of fresh air, and, except in the coldest weather, in America I have taken, in common with others of similar mind, the standing room on the driver's or conductor's platforms, on American cars, in preference to the inside. But we in England have somehow a strong inclination to get up higher, and we like to see around us from a position of vantage and freedom ; and we cannot give up our top seats, no matter what other advantages are offered.

Protection must therefore be afforded such passengers against any breakage of the trolley wire. Mr. Alfred Dickinson has met this in a very neat way, together with more important structural advantages, by putting his trolley wire on one side of the road. The matter could also be met by putting an awning over the top seats, as on the steam tram-cars in Birmingham and elsewhere.

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With the conduit system, of course, top seats would need no such provision.

With regard to electric traction in the centre and outskirts of our own metropolis, while impossible in our already too crowded main thoroughfares, I am still of opinion that lines could be laid advantageously in our wider and less frequented thoroughfares, which would relieve the congestion of the narrower streets, and at the same time afford wide and attractive views, which would draw people by such a route by preference.

For instance, let us say that one of our Westminster lights has been seeing a client in the City and is returning to Westminster,—or perhaps it would be more dignified to say that a City client has an appointment with a Westminster luminary. He is, of course, pressed for time, and sooner than go by 'bus up crowded Fleet Street and the Strand, with an exasperating wait or change at Charing Cross, he will take a ticket at the Mansion House or Blackfriars and get himself put down at Westminster Bridge by the District Railway. But if some one informed him that electric cars ran every two minutes from Blackfriars to Westminster Bridge *via* the Victoria Embankment, and would land him there in ten minutes, I am very much mistaken if he would not take that route.

At any rate, if nothing short of a cab would suit our City man on such a visit, I suspect that the route named would be much sought after and appreciated by the ordinary travelling public; and this noble thoroughfare would be made a scene of life and energy, and be an attraction to many who cannot spare the time to walk along it. I respectfully commend this to the notice of the London County Council as a scheme that might well be combined with that of the river frontage electric lighting, and be a work of great public utility.

I only mention this in passing as an instance, but we have only to look around our outlying districts and see plenty of paying routes to our breathing spaces, open commons, parks, &c., where neither horses nor the railroad are practicable, where the ascents with heavy loads cannot be tackled by horse-flesh, and railroads would mean cuttings and tunnels on the level; but

the electric car can easily climb hills and take heavy loads of people to where they can get Nature's best tonics—long stretches of view and pure air. The termini of such lines could be situated with the greatest advantage at or near the suburban railway stations. Mr. Wilkinson.

The points I have hitherto brought forward have been almost entirely confined to experience in the States, where, in fact, most experience has been gained; but in so far, at least, as administrative, industrial, and public opinion in this country may be influenced by what has been done on the New Continent, there is much to be said on the progress made by our compatriots in the Dominion of Canada.

As in the States, the life is vigorous and expansive, but none the less in true accord with British instincts.

The cities of Montreal and Toronto are well provided with electric tramways, and the citizens avail themselves of this means of transport in living out some distance in the suburbs. The streets of the city of Toronto are as well laid out and kept as those in our own metropolis, the roadways being asphalted, and the footways well flagged. The overhead trolley is everywhere in use, and æsthetically does not intrude upon the general appearance of the city.

In Montreal, I went over the new power station of the Montreal Street Railway Co., then being fitted up with engines and boilers of 3,600 H.P The engines and dynamos were of Canadian manufacture, and the boilers were from England. This station was designed to meet the needs of the entire tramway system of the city after converting all the remaining horse cars into electric. The change meant an electric supply to something like 150 motor cars, with nearly as many trailers.

The rails in these two cities are of the grooved girder type, imported from Great Britain, 72 lbs. to the yard, and laid, as in this country, directly on the concrete foundation of the roadway with tie rods, but not sleepers.

While scarcely coming under the head of ordinary road tramways, the electric line from Queenstown to Chippewa, Ontario, is of special interest.

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The line follows the western side of the Niagara Strait near enough to the edge of the cliff to obtain magnificent views of the Falls and rapids, and was built by the Niagara Falls Park and River Railway Co. on Government ground, rented at £2,000 per annum, with the object of developing tourist and excursion traffic. It was only opened in May, 1893, and in that summer 10,000 to 15,000 people travelled on the line per day, at fares ranging from 2½d. to 3s. The latter is the return fare covering 23 miles. The takings during July and August were £500 per day. Land in the vicinity fetched £40 an acre when the line was first constructed. After six months' working it fetched £100 per acre, and no doubt will continue to rise, as the company intend laying out a few good hotels, and the facility of locomotion promises the starting of good residential property on the heights, which have hitherto been unapproachable except at rates particularly gratifying to cabmen.

The line is of the most substantial character, laid as a steam railroad, with 56-lb. rails, on sleepers, and ballasted. There were last year 24 motor cars, 10 of which were "observation cars," and 18 trailers. The observation cars weigh 20 tons loaded, and carry over 100 people easily. They are specially constructed with two rows of seats, fitted lengthways in the car, one above the other, and facing one way, so that everyone can get the view.

The usual thing is to run one motor car and one trailer with over 150 people aboard.

It was anticipated that there would be a fair amount of traffic in winter as soon as the ice bridge was formed below the Falls, as this is a great attraction. There was a foot of snow on the ground when I went over the line, but the travelling was most agreeable, as the cars were kept up to a comfortable temperature by electric heaters under the seats, supplied with current tapped off the circuit. Six of these heaters in a car, three on each side in multiple series, consumed 2 amperes at 500 volts, and would therefore cost less than 3d. an hour. The cars were well lighted by glow lamps, and the route was lighted by clusters of these lamps placed at the top of every alternate pole.

I am much indebted to Mr. W. T. Jennings, C.E., of Toronto,

Mr. Wilkinson

who designed the line and power plant, for his courtesy in showing me over the line and affording me information for this paper. The power is derived mainly from the Falls, a head of 57 feet clear fall being utilised, which now supplies three wheels of 1,000 H.P. each, one being in reserve. To meet the heavy loads when climbing the Queenstown heights, up a grade of 1 in 20, it was found more economical to put a small additional power house down at that terminus, with dynamos driven by steam power, than run two 37/15 or one 37/12 insulated feeders from the water-power station, a distance of nine miles, which would have cost at least £2,600.

This fact is significant of economies to be effected in transmission, and seems, as far as long lines and heavy traffic are concerned, to point to a practical conclusion as regards the maximum power per station in street tramway power plant similar to that enunciated by Mr. Crompton with reference to electric lighting stations, namely, that there is a limit to the amount of power it is economical to supply from one point only. The cost of insulated feeders comes in as a considerable item in first cost on lengths above five miles, and the loss of voltage and energy in transmission of the current is a continuous one. I think it worth while to consider high-tension transmission by underground feeders and the use of motor-transformers, or the direct use on ordinary lines of what the Americans call "boosters," or motor-generators; or, again, the three-wire system, or the establishment of power stations situated, not as they are now, namely, in the centre, from which lines radiate outwards, but at the most distant points, and feeding towards a centre. The stations are situated in this manner in the city of Cleveland, Ohio, and, through the courtesy of Mr. Wason, I am pleased to be able to show you a day-load curve (see Plate B.) The largest curve, which reaches 3,400 amperes at seven o'clock in the morning, is from the original station, and you will see the curves below of two new stations feeding into the same network, and which together add another 2,400 amperes at the same hour. The curve was that for the day previous to my visit, when the ground was covered with frozen snow and the temperature was 9 degrees of frost. Of the

Mr. Wilkinson. total current, about 600 amperes is used to drive motors in shops and factories.

It should be pointed out that, while the curve gives a general idea of the average load, and the hours of maximum and minimum load, the area does not give the integration of the total output, as the readings were only taken half-hourly, and the changes of load on a tramway circuit are too frequent to admit of accuracy in any readings of current at longer intervals than a few seconds.

I have specially made mention of the Canadian line at the Falls on account of four points which are deserving of notice and reflection. The first I have already touched upon, namely, the cultivation of tourist and excursion traffic along a route where attractive views and fresh air can be obtained.

The second point is that the termini are in close proximity to two main lines of railway—namely, the Michigan Central and the Grand Trunk—which not only increases the tourist traffic, but creates a traffic of its own independent of scenery, but with the scenery thrown in.

The third point is that the line passes near an agricultural and fruit-growing district, and special freight cars have been added for conveyance of these crops to the railways at rates lower than could formerly be obtained, and at the same time profitable to the tramway company.

And, fourthly, the line forms part of a through connection between the two large cities of Toronto, on the North, and Buffalo, on the South, by steamboat connection at the termini of the line.

The line has already been described to you by Mr. W. H. Preece, in his paper at the beginning of last session, in a more fascinating way than I can hope to bring it before you. When Mr. Preece first enlivened us by his presence at the Chicago Exposition, everyone who was bound to admit to him that he had not seen that line at the Falls felt somehow at once to have lost half his stature.

Mr. Preece, like all Englishmen, when he takes his seat in a tram-car or railway carriage, likes to go ahead, and I think his

experience of the elevated steam railway, or so-called "rapid "transit" line, in Chicago will agree with mine—that it is not much quicker than the street surface cable and electric lines, and does not compare favourably with our own suburban railway systems. I suppose our railways in and around the metropolis, which I think are second to none in the world for speed and safety, somewhat spoil an Englishman for any more tardy lines. Mr. Wilkinson

While it is evident that the combination of fortuitous conditions in the Canadian Falls line is very exceptional, yet I am of opinion that, by keeping these and other favourable conditions in view, there are many districts in our own country where electric tram lines could be put down at once with advantage.

I have drawn attention in my paper to some points in power station plant, more particularly with reference to fly-wheel strains under the exceptionally sudden changes of load in street tramway work, which are sometimes the cause of serious mishaps. The ordinary fluctuations in load are caused by the starting or stopping by chance of a number of cars at the same instant, the variations being at times from over full load to quarter load; and the more excessive fluctuations are due to short-circuits, or the sudden release of load by automatic circuit-breakers. In one large station of 4,000 H.P. I was informed that the average was 20 short-circuits per day. Most of these were temporary, and caused either by high winds shifting some of the overhead gear, or falling telegraph or telephone wires, but in exceptional cases caused by the trolley wire itself breaking and falling on to the rails or ground. An overload or short-circuit, when driving by belt, puts a sudden brake on the periphery of the fly-wheel and a shearing strain on the spokes.

The belt, of course, slips, but at times it parts or is thrown off, and in the course of its career sometimes damages the governor and leaves the engine uncontrolled, under which circumstances it is rare if there is time to shut down before something goes; and, as they tersely put it on the other side, it is best to get behind a pillar and await developments. The bending strains set up in the rim by centrifugal force in a racing engine appear to have been the cause of more fractures of the wheel than the shearing strains.

Mr. Wilkinson.

The reason for wheels with one to two thousand foot-tons of stored energy is, presumably, to secure regulation of speed in engines having a small number of steam admissions per unit of time; but I think it will be admitted that the governor has more chance of producing an immediate effect upon the speed when there are a large number of admissions per unit of time, and there is the additional advantage in the use of much smaller and solid fly-wheels of approximately one-tenth the stored energy, and therefore well able to "stand the racket" with safety.

Regarding the use of belts, I think engineers in the States are coming to see that it is worth while to put a little more material in the generators and do without these weak links in the chain of transmission. At any rate, I noticed many of the newer plants were direct-driven, with marine-type engines.

I admit that there is something very stately and imposing in a long row of trip-gear engines with large fly-wheels and belts. I enter very keenly into the enjoyment of such a sight, and am also much impressed by the number of yards super. in stone and brick outside the building, and feet super. of floor inside; but when we have to consider capital cost of works, and adaptability of plant to get down in good shape to its work under trying conditions with safety, we may wisely let such considerations take a secondary place.

Our corporations would do well to study the needs of the people in and around their townships; and I am confident that the good sense and judgment they, as business men, always display in schemes for the benefit of their townspeople, would lead them to select paying routes for light railways not paralleling the ordinary railways, and which would not only meet the needs of the daily transference of the population, but take in and out light market freights, and, by affording healthy travel, tend to foster the energies of their townspeople.

The success of the Isle of Man Electric Tramway is an indication that such needs of the population do exist, and when catered for and fostered, result in benefit to themselves, the promoters, and indirectly to the country at large.

As I have before pointed out, such lines create traffic of

themselves, and raise the value of land and property in the vicinity. Mr. Wilkinson.

I venture to predict that if facilities for reasonably quick and cheap travel between the suburban districts of our large towns and outlying villages were afforded the masses, they would gladly avail themselves of them. Such facilities would afford them enjoyment of open space, pure air, and opportunities of observing life in different grooves to their own on the one hand, and cheap carriage for market produce on the other, which could only have a beneficial effect, and would most probably bring about an alleviation of agricultural discontent, and a mitigation of the crises resulting from the labour problems of the day.

Speeds can be accelerated somewhat in the open country.

The recent proposal made by the Board of Trade to the Chambers of Commerce and other bodies interested, to discuss the question of light railways, is an action of much importance to the country at large, apart from the consideration of systems of travel, and one that I am sure is fully appreciated by this Institution.

The questions of land, permanent way, signals, staff, level crossings, and fencing in where it is not practicable for such lines to take the high road, are to be brought forward.

The Board of Trade has ever shown the most ready spirit to favour electrical enterprises in the best interests of the public, with due regard to the protection of property, as exemplified in Electric Lighting Orders and in the drawing up of the present practical code of Regulations for Electric Railways; and I have no doubt that the question of operating light railways in suburban, inter-urban, and country districts by electricity will be thoroughly brought forward by the engineering and electrical trades section of the London Chamber of Commerce, in response to the esteemed invitation issued by Sir Courtenay Boyle.

We can count on our fingers the number of electrically worked roads in the United Kingdom, and they can only claim a short mileage; but I beg to assure our American cousins that this is not because we are afraid of running into the sea. There are more people to the square mile in our large towns and cities

Mr. Wilkinson. than in more roomy America, and our streets are not mapped out on squared paper before a town is built. Hence the special character that must necessarily pervade our designs in electric roads.

After all, mileage is not the only gauge of advancement. What will do for one American city, generally speaking, does for a second, a third, and a thousand. It is refreshing to notice the individual character, in institutions, public works, and speech, that obtains in the different townships of our country, in contrast to the sameness of cities in the States. At the same time, this means more investigation into the needs of the people and design of road, calling for greater achievements, although not on so large a scale.

Taking the cities of Liverpool and London, for instance, we have our elevated electric road, our subterranean electric road, and a second now building, which are engineering works of the highest order, and exceedingly well adapted to the necessities of our traffic. I call these achievements to be proud of.

In conclusion, I may be permitted to say that, while judging such information as I could bring to bear upon the question as it affects us in this country to be of interest to our engineers, as it certainly has been given me with infinite open-handedness and cordiality by my American friends, I do not cease to recognise the great labours and genius of our great engineers and electricians who have frequently addressed you in this room, and from the Presidential chair in both this Institution and the Institution of Civil Engineers, and whose indomitable perseverance and energy have led the van in laying the earliest electric rails in the United Kingdom.

The President. The PRESIDENT: Gentlemen,—After the demonstration of applause which has followed the reading of the paper, I need hardly ask you to pass a formal vote of thanks to Mr. Wilkinson, either for the paper which has already been published in the Proceedings, and which I have no doubt every one of you has read with interest, or for these additional remarks which he has just given us; but before I call upon you to discuss those papers, I think we had better hear another paper on a similar subject which has been submitted by Mr. R. W. Blackwell, Foreign

Member, and Mr. Philip Dawson, Associate, on "Electric Traction, "with Special Reference to the Installation of Elevated Con-"ductors."

The following paper was then read:—

ELECTRIC TRACTION, WITH SPECIAL REFERENCE TO THE INSTALLATION OF ELEVATED CONDUCTORS.

By ROBERT W. BLACKWELL, Foreign Member, and PHILIP DAWSON, Associate.

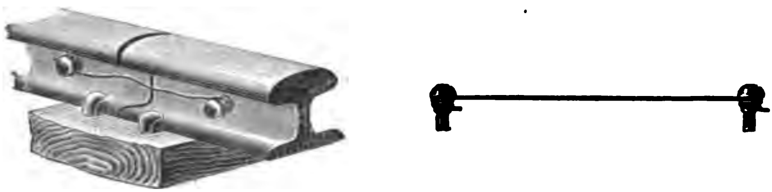
In conversation with Mr. Wilkinson a few days ago, the suggestion was made that some supplementary memoranda relating to electric tramway practice—collected during the past six months which we have passed in studying construction on the principal American lines, and in visiting the late large Continental installations—might meet with your acceptance; and it was also thought that an exhibition of apparatus employed in erecting and working elevated conductor lines would be of interest at this juncture. Mr. Blackwell and Mr. Dawson.

The marvellously rapid and successful introduction of electric traction in the United States is now an old story. That 600 electric tramways are there operating nearly 9,000 miles of track and 20,000 cars,—that nearly three-fourths of the tramway movement of the country is electrical,—that £45,000,000 is there invested in electric tramways,—and that this tremendous result has been, to all intents and purposes, effected within five years,—cannot but appeal pleasantly to the electrical engineer. Germany, France, Belgium, Austria, Switzerland, are already investing millions in electric traction, and there seems every reason to believe that England will shortly join the march of progress.

Probably no practical point in electric traction was less understood a few years ago than "rail-bonding," and a few words may be added to what has been said on that subject. Its importance has but recently been appreciated, and it is of *first* importance. It may be taken that the bonds connecting rails

Mr. Blackwell and Mr Dawson.

should be, as nearly as possible, of the same current capacity as the metals themselves. If a 70-lb. rail be used, the sectional area of copper bonds should be as nearly as possible seven-sixths of a square inch, the ordinary steel rail having approximately one-sixth as much conductivity as commercially pure copper. This would exceed nine No. 0 copper wires.



Old-Style Rail-Bond.

When electric roads were first constructed, a No. 4 galvanised iron wire was considered sufficient!

The contact surface of bond and rail should be as large as possible. With heavy bonding and insulated return-circuit feeders, the danger of corroding gas and water pipes (a danger that has been greatly and unnecessarily exaggerated) is practically *nil*. The Toronto, Baltimore, Salt Lake City, and many other systems may be cited in support of this statement. In cities earlier equipped, where the lightest of rail-bonds and return feeders were employed, and very heavy current dealt with, serious results undoubtedly ensued, as at Boston, where electric traction was first installed on a large scale. By the use of modern appliances the trouble there has almost ceased to exist. The tramway company employs special workmen to accompany gas and water construction gangs, and to connect all water and gas pipes laid in the neighbourhood of the power house to heavy bare copper cables returning to the stations. It must, however, be borne in mind that in that city an approximate total of 13,000 E.H.P. has to be dealt with by the three power stations of the West End Street Railway Company. The following are the figures of January 27th, 1894, on which day 577 cars and 71 snow ploughs were running:—

Mr Blackwell and Mr. Dawson.

Stations.	Hours run.	Mean Current for the Day.	Maximum Current.
Aleston	16	1,203 amps.	1,580 amps.
Cambridge... ..	18	4,088 „	5,425 „
Central	24	12,706 „	14,400 „

The average monthly car mileage of this line in 1893 was 1,325,000 miles.

Professor Jackson, of the University of Wisconsin, has found by experiment that the chemical composition of the soil has a great influence on corrosion. The most favourable to it, and having the smallest resistance, is that in which there is the greatest proportion of chlorides. Nitrates come next, and sulphates last.

If, after all ordinary precautions are taken, corrosion still continues, bare copper cables are connected to the negative terminal of the generators at the switch-board, and to all pipes in the neighbourhood of the station.

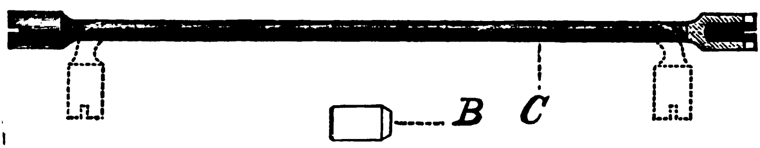
So far as possible the use of earth for the return circuit should be avoided. In conversation lately with Mr. Sprague, who developed the traction department of the Edison Company, he laid great stress upon the advisability of laying the rails upon good stone ballast, and coating all bonds and connections with insulating and preservative compound, such as the well-known "P. & B."

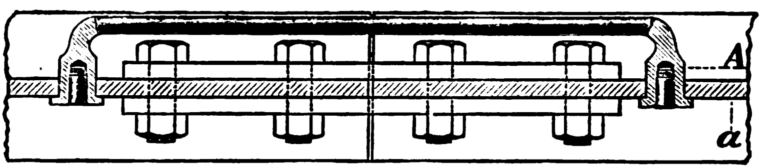
The practice of laying bare copper wires along the whole length of the track, once regarded as indispensable, is now practically abandoned. It has been found that wire so laid rapidly deteriorates and wastes away. All the copper is put into the bonds, the rails are cross-connected approximately every 90 feet, and where the volume of current exceeds the economical carrying capacity of the bonded rails insulated return-circuit conductors are employed. A number of rail-bonds of approved make are on the table. It is interesting to compare them with this galvanised iron wire bond of a few years ago. Here are also two samples of rail-bonds laid

"Brooklyn" Rail-Bond

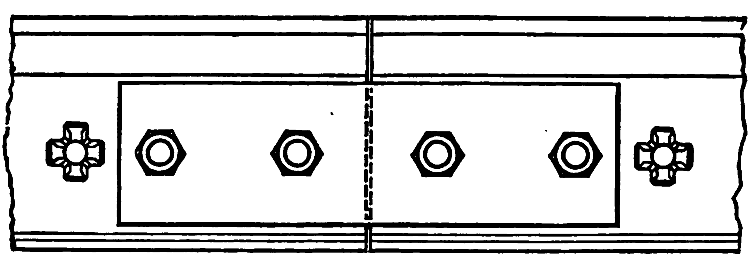
Mr. Blackwell and Mr. Dawson.

some three years ago—one of copper, the other iron. You see that both have entirely given way. They were utterly insufficient to carry the current of the line, and are examples of what was considered good bonding when they were laid. The iron bond when laid was electrically welded to the rails, but the process employed was evidently unsuccessful. This "Brooklyn" rail-bond, as its name implies, has been extensively used in that city. It is a simple strip of copper, so bent as to provide for expansion and contraction. A drive-fit tapered iron rivet at either end holds it to the rails. This "West End" bond is largely employed by the Boston tramways. An iron taper is brazed on to the copper wire at the points where the bond is driven through the web of the rails, and a soldering sleeve connects the free ends of the wire. This "Vail" bond is composed of





SECTIONAL VIEW.



ELEVATION VIEW.

"Chicago" Rail-Bond.

flexible stranded copper cable, welded into heavy terminals, which are provided with copper riveting projections to be forced through

the web. This "Chicago" rail-bond is more elaborate and effective. Mr. Blackwell and Mr. Dawson

The rail-bond, C, is a copper rod or wire having tubular or thimble-shaped terminals, which are bent at right angles to the bond, and, with its two tubular terminals, is composed of one solid piece of rolled copper.

The tubular or thimble-shaped terminals, A, are inserted into holes through the web of the rail, *a*, and the slitted end of the terminal, A, is spread or clinched over on the rail with a hammer and punch: this holds it from drawing back out of the hole.

The drift pin, B, which is larger than the opening in the tubular or thimble-shaped terminal, A, is then driven into said terminal, thus expanding it and wedging it into solid contact with the surface of said hole through the web of the rail, *a*, making an absolutely solid joint, from which every particle of air and moisture is excluded, and proof against corrosion or electrolysis.

Size of Wire.	Diameter of Hole in Rail into which Terminal of Bond fits.	Diameter of Hole in Terminal.	Depth of Hole in Terminal, not including Point.	Diameter of Pin.
0000	$\frac{7}{8}$ inch	$\frac{7}{16}$ inch	1 inch	$\frac{1}{2}$ inch
000	$\frac{3}{4}$ "	$\frac{3}{8}$ "	1 "	$\frac{7}{16}$ "
00	$\frac{5}{8}$ "	$\frac{5}{16}$ "	1 "	$\frac{3}{8}$ "
0	$\frac{1}{2}$ "	$\frac{1}{4}$ "	1 "	$\frac{5}{16}$ "

It must be noted that the enlarged terminals are of sufficient diameter to avoid any choking of the current as it passes from the rail into the bond. As has been before said, the contact between rail and bond should be as near as possible seven times the sectional area of a bond wire sufficient to carry the given current. The sections shown exhibit the construction very fully. While the solid copper bond possesses all the flexibility found to be necessary, it is made, when desired, with flexible stranded copper cable between the terminals. Four hundred and fifty miles of electric railways in and about Chicago use this bond.

Mr. Wilkinson has fully described and illustrated other types of bonds, to which it is unnecessary to again refer.

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It may be said, broadly, that no surface contact between bond and external web of rail has shown any permanent value.

Whether electric welding will eventually take the place of all bonding is still an undecided question. It has not yet stood the test of practical use on a large scale for a sufficiently long period to pronounce an opinion.

When first introduced in Boston it was not successful, many rails breaking near the joint after some months' use. The process has since been improved, and a trial section of line was in course of being welded when the "West End" Street Railway was visited last June. Seven miles of welded track have given satisfaction for some months in St. Louis. Over 100 miles are now being welded in Brooklyn, and the result of this trial will demonstrate, after a year or two, the value of welding. At present it takes from 10 to 15 minutes to make a welded joint, and, on an average, a current of about 250 amperes at 550 volts is necessary, which is transformed into an alternating current at 2 to 3 volts pressure. Approximately, each joint costs 12s. to 15s. It is said that the pioneer company in electrically welding rails has already invested over £120,000 in experiments.

It is worth mentioning that modern American practice is to butt the rails, allowing nothing for expansion, wherever the streets are paved. The result is a nearly perfect joint.

With heavy cars, having at least 4 to 5 tons load on each axle, this is of the highest importance.

A number of sections of standard American tramway rails are shown, and you will see from them that the highway authorities there are not quite so strict as they are in England, and allow of the use of a rail which presents much less obstruction to the easy running of a tram-car wheel.

Mr. Wilkinson refers to the possible adoption of the three-wire system for electric tramways. That system has been in satisfactory use in Portland, Oregon, for the past four years. Compound-wound generators, working at 500 volts without load, and 550 volts with full load, are used. The success of this system depends upon the load of the various sections being nearly balanced. At Milwaukee, where local conditions did not allow of

proper balancing, the system was tried, and given up as a failure. The three-wire system was introduced at Portland because the generating station was three miles away from the nearest point of the line, and the cost of feeders would have been necessarily heavy. By the three-wire system 1,100 volts could be used, −550 and + 550, between each two sections of trolley wire. The rails were connected to the neutral terminal at the switch-board. The average load on this station is 1,500 H.P. It is located near a huge lumber mill, and the fuel is carried by automatic conveyers directly from the waste lumber yard into the furnace. Several tramways derive their power from this station, at a cost of about 25s. per H.P.-month, 18 hours' daily work. Thomson watt-meters register the current used. The station pays about 40s. a day for its supply of fuel. Mr. Blackwell and Mr. Dawson.

The enormous carrying power of an electric tramway, at a pinch, is an interesting feature. The following figures, given by Mr. Bowen, of the Chicago City Street Railway Company, show the work done by his electric line on "Chicago Day" at the World's Fair:—

Fifty-one double-motor cars, 10 single-motor cars, and 73 trail cars were in operation over 26 miles of track. During the day 208,575 passengers were carried, and 11,271 car miles run. The maximum output at the power house was 17,000 amperes, and the average for 20 hours about 1,050. The minimum current registered was 750 amperes, and the average station pressure 540 volts. The ratio of expenses to receipts on this line is 40 per cent.

The following figures we have already published in a communication to *Engineering*. They are, however, sufficiently interesting to be placed before you.

The largest electric tramway equipment in the world is that of the West End Street Railway, in Boston, U.S.A. Its adoption of electrical motive power practically established the economic value of that method of operation. The following figures are extracted from its annual reports :—

Mr. Blackwell and Mr. Dawson

To November 30 of	1888.	1889.	1890.	1891.	1892.	1893.
Total miles of track	...	233·24	234·69	244·00	259·80	268·33
Miles electrically equipped ...	...	...	65·46	81·23	148·04	182·50 (*e*)
Number of horse cars	1,584	1,794	1,694	1,662	1,226	826
„ electric cars ...	...	47	337	469 (*a*)	1,028	1346 (*f*)
Total revenue miles run ...	15,431,758	16,573,831	17,665,360	17,462,572(*b*)	17,498,660(*c*)	18,669,809(*d*)
Electric revenue miles ...	...	...	...	4,588,186	9,622,000	14,189,054
Percentage of expenses to earnings	82	82	77	74·4	70·8	68
Investment in electrics dols.	...	412,600	1,510,321	...	5,752,694	7,608,069

(*a*) The long cars introduced at this time, and now almost exclusively used on the company's electric lines, are almost twice the size of the regular two-horse car.

(*b*) Electric mileage ... ... 26·27 per cent. Horse mileage ... ... 73·73 per cent.

(*c*) „ „ ... ... 48·63 „ „ „ ... ... 51·37 „

(*d*) „ „ ... ... 76·17 „ „ „ ... ... 21·83 „

(*e*) And 25 additional miles partially electrically equipped.

(*f*) And 24 electric snow ploughs.

Attention is especially directed to the decrease in percentage of working costs to gross receipts, which has varied almost directly in proportion to the introduction of electric plant. This reduction has been made notwithstanding the fact that the additional investment required for the introduction of electric plant had to be provided for, and that such part of the company's former plant as was rendered useless, or disposed of at a loss, had to be written off. Mr Blackwell and Mr. Dawson.

A comparison between the tramways of London (population, 4,306,411 in 1893) and Boston (population, under 450,000 in 1890) is interesting:—

	London.	Boston.
Miles of street operated	125⅝	—
„ single track	250 approx.	268⅓
Number of cars	1,080 (*a*)	2,172
Car miles run	21,924,290 (*b*)	18,669,809
Total working expenses	£885,967	£910,147
„ receipts	£1,070,578	£1,338,515
Net receipts	£184,611	£428,368
Percentage of expenses to receipts	82·7 (*c*)	68
Total capital invested	£3,533,177	£4,435,000
Rate of interest paid on ordinary shares	3·32 per cent.	9 per cent.

(*a*) London uses top-seat cars, Boston does not. Boston has to keep a double set of cars; open for summer, closed for winter.

(*b*) London has the greater number of car miles run. The majority of Boston cars are much larger than the London ones.

(*c*) Boston investment includes £1,500,000 spent during the past five years on re-equipping electrically.

If London's percentage of expenses to receipts could be reduced from the present 82·7 to 70 per cent., net receipts would be increased to £321,174; if to 60 per cent., net receipts would be £428,231.

It is almost unnecessary to call attention to the fact that the cost of material and labour involved in the re-equipment electrically of a tramway is much higher in America than in England.

Mr. Blackwell and Mr. Dawson.

In the early days of electric traction, no greater annoyances fell to the lot of the much-tried tramway constructor than those which seemed inseparably connected with the suspension and effective insulation of the conducting wire. No material was obtainable possessing the happy combination of strength, durability, and high insulation with inconspicuousness; interchangeability of parts was unknown; and unsightly, rough-and-ready expedients were used wherever difficulties in erection were encountered. From 1884 to 1889 no insulator better than paraffined wood or porcelain could be obtained. This is the best device the Bentley-Knight Electric Railway Company could evolve to support a bar copper conductor in its conduit system laid in Boston in 1888. As you will see, it is composed of a block of porcelain leaded into a malleable iron holder, and having a brass support for the conductor leaded into it. All of the earlier elevated conductor lines were dependent for their insulation upon the wooden poles by which they were supported, and in wet weather the resultant leakage was a very serious factor.

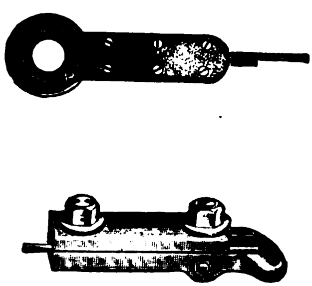
With the introduction of iron poles, and the development of motors and power plant, something better and more permanent became a necessity.

The wide extension of electric traction is largely due to the enterprise of independent manufacturers, who, seeing a great and growing need, undertook the elaboration of a system of electric tramway supplies to meet the demand, and relieved the electrical companies of constant consideration of the details necessary for safe and economical transmission of current from power house to car motor. The taut and workmanlike overhead line of to-day, in erecting which the lineman has had at hand a compact and appropriate device for every insulating or supporting point, differs widely from the unsightly webs which were the rule in earlier years.

Your attention is called to the various appliances on the table. They fairly represent the best known and most widely used apparatus. You will note the strong external resemblance between the various makes wherever an appliance for a specific purpose is in question. We will not go into the question as to

whether any one insulating material has greater merit than another. The specimens shown include several distinct makes of homogeneous and fibrous insulating substances, the composition of which is a manufacturers' secret; and also insulators of compressed mica, and of solid sheet mica ingeniously compressed between metallic parts, and supplemented externally by a special insulating compound. Mr. Blackwell and Mr. Dawson.

Of that important factor, the trolley wire itself, little need be said. The universal American practice is to employ No. 0 hard-drawn copper. Many Continental lines have employed lighter trolley wire—in some instances as small as 6 millimetres—and some use larger. It may be taken, however, that No. 0 is the size that gives the best all-round results. Phosphor-bronze is of doubtful utility as a substitute for hard-drawn copper, the increased tensile strength being more than overbalanced by the reduction in conductivity. The manufacturer of the trolley wire should guarantee 98 per cent. conductivity or better, and perfect joints, and should deliver wound on special reels in mile lengths. Good running and a low rate of depreciation depend largely upon the exactitude with which the trolley wire follows the line of the metals, and pains taken to ensure a smooth and even path for the trolley wheel are always well repaid.



Terminal and "Come Along" Clamps for Straining Trolley Wire.

Self-Locking Pole Ratchet for Span Wire.

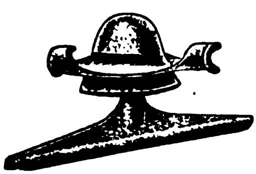
The span wire almost invariably employed is a seven-wire galvanised iron signal strand, either $\frac{1}{4}$ or $\frac{5}{16}$ inch diameter, like these samples.

In some places local atmospheric conditions have rendered it

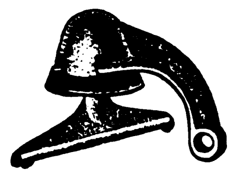
Mr Blackwell and Mr. Dawson.

advisable to substitute silicon or phosphor-bronze span wires for the ordinary galvanised iron.

In the selection of the line of appliances to be used, the nature and needs of the individual road must be borne in mind. For a suburban line and light traffic, where economy in first cost is a first requirement, this "Ætna A" type insulator serves the purpose well. You will see that the series in this type includes a straight line insulator, single and double pull-off for curves, and a bracket arm hanger. The construction is shown in this section.

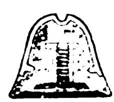


"Ætna A" Straight Line Insulator

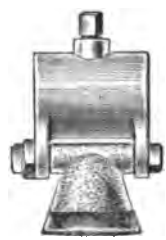


"Ætna A" Single Pull-off.

"Ætna A" Double Pull-off.



Section of "Ætna A" Insulator.

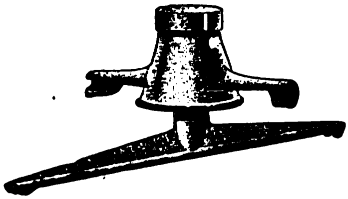


"Ætna A" Bracket Arm Hanger.

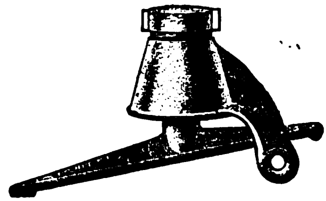
In this type, the homogeneous mass of insulating material, while still in a plastic state, is forced under heavy pressure into a casting provided with internal flanges to hold it securely in place, and external points to which the span or strain wires may be attached. The threaded thimble is moulded into the insulating material at the same time. The threads are made to take $\frac{7}{16}$ or $\frac{5}{8}$ inch screw studs, according to the strain they are to sustain. The metallic parts, which partially protect the insulating substance, are of either bronze or malleable iron. In this type the strain and weight of the trolley wire is taken by the insulating material itself.

This is the type of insulated suspension employed by the

South Staffordshire, Douglas and Laxey, and Guernsey lines, and many Continental and colonial roads. Mr. Blackwell and Mr. Dawson



" West End " Straight Line Insulator.

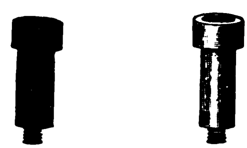


" West End " Single Pull-off.

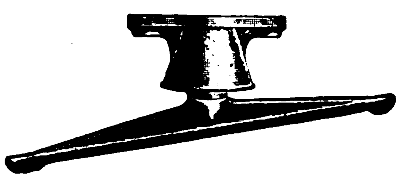
" West End " Double Pull-off.

" West End " Bracket Arm Insulator

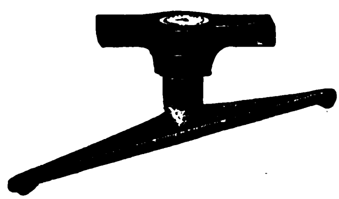
" West End " Spring Bridge Insulator, with " Anderson " Mechanical Ear.



" West End " Insulated Bolt and Bronze Feeder Plug.



" West End " Bridge Insulator.



" West End " Car House Insulator.

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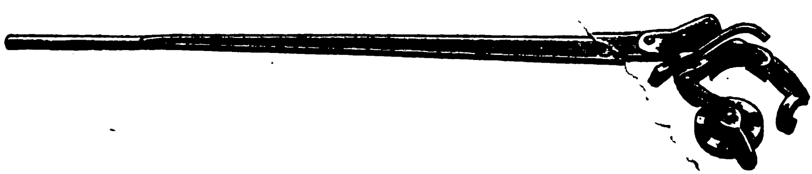
To supply the needs of tramways where constant and heavy traffic is to be expected, and where security to the service is of far more importance than small economies in first cost, the "West End" type of insulating material has been evolved. This series is more elaborate than the former, comprising a straight line insulator, single and double pull-off, bracket arm hanger, and bridge, spring bridge, and car house insulators.

These are far more substantial than those first described. The essential difference in construction is that the insulation is wholly protected from injury from exposure or chance blows, by a metallic skirt, and that no part of the strain comes upon the insulating material itself, the load and strain being wholly taken under all circumstances by the heavy metallic parts of bronze or malleable iron. The insulating part is a bronze or steel bolt, heavily coated under pressure with non-conducting material, the head of which fits closely into a recess at the top of the protecting casting, and is firmly held there by a screw cap. These bolts are interchangeable throughout, and can be slipped in or out at any time. When it is desired to bring a feeder into the line, the insulating bolt is slipped out and a metallic "feeder plug" of exactly the same size takes its place, thus throwing the whole hanger into circuit and allowing an insulated feeder wire to be attached to it in exactly the same way as an ordinary span wire would be.



Special Tool for putting up "West End" Straight Line Hangers.

A special tool is used in putting up "West End" straight line hangers, and much facilitates the labour of erection. The casting is held in the fork at the top of the tool. The span wire fits into the groove of the wheel, and a single movement of the lever snaps the wire into position.

By the use of this "West End" type of apparatus, the span wires can be erected, and the castings inserted at the fixed points

of suspension, before the insulating material is brought on the line. Ears can be soldered to the trolley wire and attached to the insulator afterwards, and there is a minimum of leakage through moisture. As an illustration of the care taken to supply each need, I would call your attention to the "spring bridge" insulator, used under bridges and elevated railway structures and in tunnels. As the fixture is, of necessity, rigidly attached to the structure above the line, a yielding support is provided in order that the trolley wheel, at high speed, may not strike a point without flexibility and have a tendency to jump the wire. The spring is protected by a galvanised iron case, and the insulating bolt within has a fluted metal covering, which preserves the insulation from injury by chafing, and prevents the bolt turning. Mr. Blackwell and Mr. Dawson

The use of high-class line material greatly facilitates both construction and operation, and in no part of the equipment can a little additional expense be incurred with such good reason.

Note how carefully the makers of both the above types of apparatus endeavour to bring span wire and trolley wire close together. Earlier styles did not possess this virtue, the span wire being led over the top of the insulator. Experience quickly showed that it was an error to separate span and trolley wire more

Old-Type Straight Line Insulators.

than absolutely necessary. To connect the trolley wire with its insulated supports, ears, or clips, are used, of which a number of varieties are on the table.

For efficiency, durability, and smooth running, nothing quite equals an ear soldered to the trolley wire, and soldered ears are almost indispensable at curves or points of heavy strain. However, it takes skilled labour and quite one-third longer in time to erect a line using soldered ears throughout. I would especially call to your attention the fact that the blow-pipe must not be

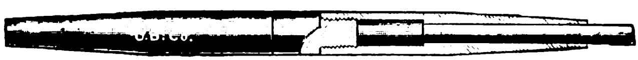
Mr. Blackwell and Mr. Dawson. used in erecting a trolley wire with soldered ears, but instead, heavy grooved soldering irons, like the one shown, must be employed. The use of the blow-pipe softens the wire, and renders it liable to break.

A trolley wire must be "anchored" at least every mile of straight line, and always at either end of every curve. Special ears are provided to which the anchor wires can be readily attached.

Anchor Ear

Splicing Ear.

Special ears are also used for joining together lengths of trolley wire. Joints should always be made at fixed points of support. A properly soldered combination anchor and splicing ear is on the table. Should the trolley wire break at a point between supports through any accident, splicing-tubes or con-



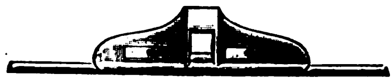
Threaded Trolley Wire Splicer.

nectors are used to quickly repair the line. There are many forms of these. In this type, to make a splice, the ends of the trolley wire are threaded with a small, suitable die furnished for this purpose, and the thimbles are then screwed on, which fit into the recesses in the coupler. The two parts of the coupler are then screwed into each other, making a strong, compact splice, but a trifle larger in diameter than the wire itself. Other ears are used for points where it is desired to make connection with feeders.

Trolley wire soldered ears are made 7, 9, or 15 inches long. Samples are shown of the regular soldering and span wire work of the linemen of the Boston tramways.

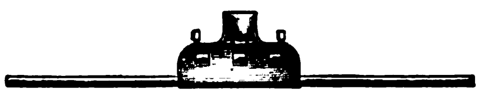
The perfect mechanical ear has not yet been evolved, although

improvements are constantly being made. Several types are on the table. The difficulty is that all mechanical ears interfere more or less with the smooth under surface of the trolley wire; and any obstruction, however slight, to the passage of the wheel is a disadvantage. This "Badger" mechanical ear is simple and effective. It is composed of two interlocking plates of malleable Mr. Blackwell and Mr. Dawson.



"Badger" Mechanical Ear.

iron or bronze, which, when placed together, leave a groove into which the trolley wire is clamped by the wedge-shaped stud of the insulator being forced into the jaws formed by the upper portion of the two plates. A pin through the stud holds the ear and stud together. Another exhibit shows the same clamping principle applied to a hinged ear, a screw stud set in the insulator being substituted for the wedge, and the pin being dispensed with. Another type shows the clamps held together by



"Anderson" Mechanical Ear.

screws. The "Anderson" mechanical ear is composed of a bronze casting grooved along its lower surface to fit the trolley wire, and a plate of hard-rolled copper bent to fit over the trolley wire, and furnished with eyes which close over slotted projections on the casting. The whole is bound together by forcing the eyes into the slots by the small screw bolts at the top of the casting. A special clamp is used to force the copper plate into position and hold it until the screws have been set up. The number of mechanical clips is legion, but none are quite up to the soldered ear. Mechanical ears are good or bad in proportion to the extent to which they interfere with the smooth running of the trolley wheel and necessitate bending of the wire. The latter is always a mistake, because, if it happens that the position of an ear has to be changed, a kink is left in the wire. It is also

Mr. Blackwell and Mr. Dawson.

an error, frequently made in early days, to allow any play or joint between the insulator and the ear.

Type "W" Trolley Clamp.

"Jewel" Trolley Wire Sling.

By the courtesy of Mr. I. Everson Winslow, we are enabled to exhibit to you a series of the Thomson-Houston insulated suspensions employed by him in the erection of the elevated conductors for the Roundhay Tramway line at Leeds. In the straight line insulator, and single and double pull-offs, the strain is taken by malleable iron or bronze castings, which spread out sufficiently to protect the insulation from accidental blows from the trolley, and to form a water-shed. A cap of insulating material, from which projects a screw stud, fits closely over the top of the casting, and the recess beneath receives a cone of the same insulating substance, through the centre of which the stud passes. When the ear is screwed up on the stud the whole is bound tightly together. Some of the insulators shown have been in regular use at Leeds for three years, and show no sign of deterioration. A bracket arm insulator, anchor ear, splicing ear, and an aerial frog, as used at Leeds, are also before you.

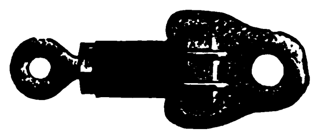
Earlier Thomson-Houston forms, showing porcelain insulation instead of the material now used, are also exhibited.

Dr. Edward Hopkinson has been kind enough to send us this insulator and mechanical ear used by the Isle of Man Tramways. It is somewhat similar to the "Anderson" ear already described, **Mr. Blackwell and Mr. Dawson.**

Section Cap and Cone Straight Line Insulator ("Ohio" Type).

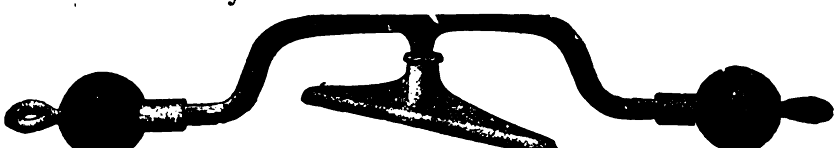
but of stronger construction. It must be borne in mind that the Douglas and Laxey line employs a sliding contact, and not a wheel. We have been unable to obtain one of the Douglas collectors for exhibition to you, as no spare ones were at hand.

Double insulation is an essential feature of first-class overhead line work. This is effected by supplementing the insulated trolley wire supports by an additional insulator at the pole-head.



"Brooklyn" Strain Insulator.

The "Brooklyn" strain insulator and turnbuckle combined



"Goose-Neck" Double Curve Pull-off.

is the best device for this purpose. Aside from its insulating qualities, a pair of the smaller size shown will take up 6 inches

"Goose-Neck" Single Curve Pull-off.

of slack in the span wire. This is extremely useful in adjusting tension when the span wires have become stretched by constant

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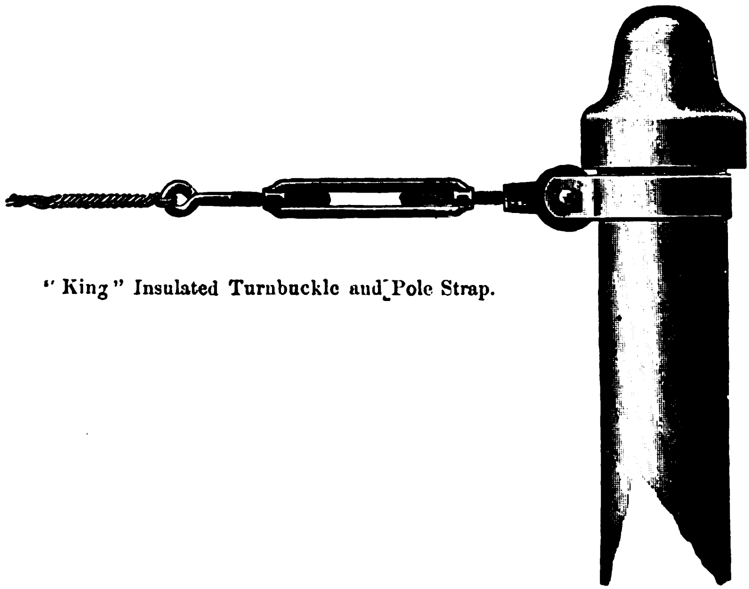
use. The larger size is adapted for terminals, and for corner poles to which a number of curve pull-off wires are carried.

The "King" insulated turnbuckle is a device of similar nature, and strain insulators of the various types are also

Globe Pole Insulator.

frequently used. All globe and strain insulators, by the way, are constructed so that, should their insulation be entirely destroyed,

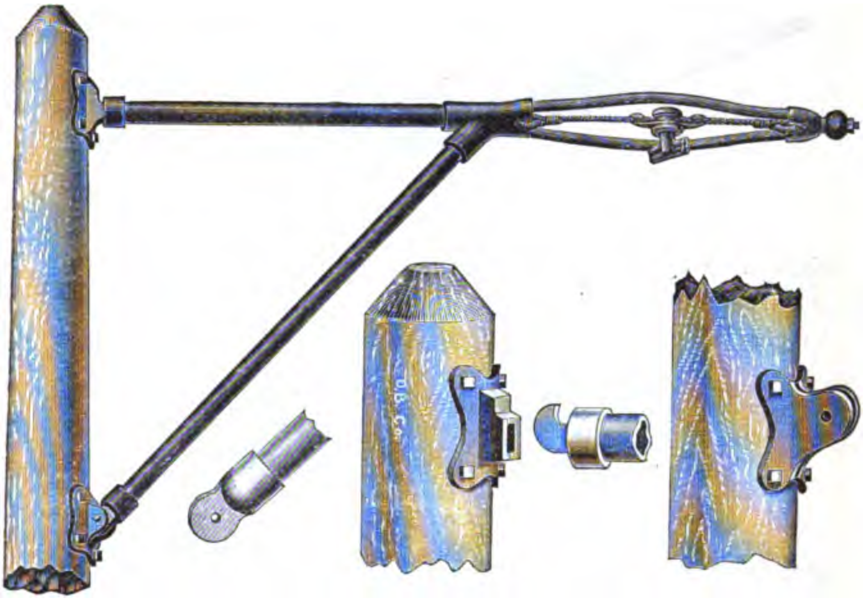


"King" Insulated Turnbuckle and Pole Strap.

their interior metallic parts would interlock and prevent the line falling. Sections and parts of insulators by a number of makers are on the table.

In cases where the trolley wire is supported by bracket arms, double insulation is obtained by the use of a tube of insulating material within the sleeve of the bracket arm hanger. In this connection we would warn you against the frequent mistake of fixing bracket arm insulators to predetermined points of the bracket. A sleeve which will slide along the projecting arm easily should always be used, as nothing but observation of the

trolley wheel as it passes under each bracket can determine the exact point at which the hanger can be most advisably fixed. Mr. Blackwell and Mr. Dawson.



Spring Bracket Arm Trolley Wire Suspension.

This feature is also apparent in the Thomson-Houston type of bracket arm hanger from the Leeds line. In this appliance double insulation is obtained by washers and tubes of insulating material, which prevent metallic contact between the upper casting in which the sleeve is formed and the lower casting from which the ear depends.

" West End " Bracket Arm Insulator. Double insulation.

A trolley wire of any considerable length should always be divided up into sections, so that an accident could not cause the whole line to be thrown out of service. Several types of section insulators are before you. Connection between the two sections of trolley wire is made or broken through a switch con-

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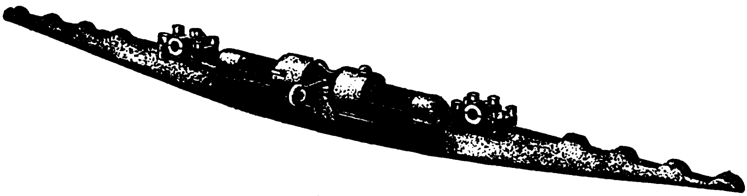
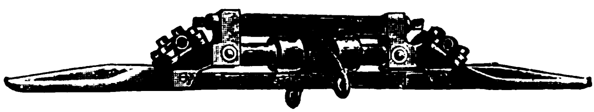
tained in a box on the nearest pole. The earlier type shown, made of brass sections insulated from each other by mica, is somewhat



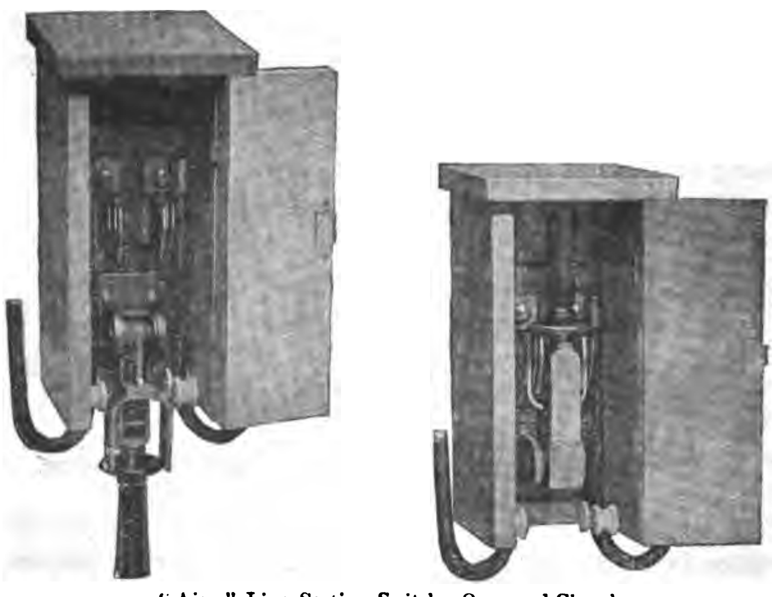
"Ætna" Section Insulator.

clumsy. You will note that the insulation of the two later forms is effected by bolts similar to those used in the "West End" hangers, and that the latest and most improved type has the



"Ætua" Section Insulator. (Straight under-running.)

great advantage of being "straight under-running," allowing the trolley wheel to pass under it without the slightest "dip."



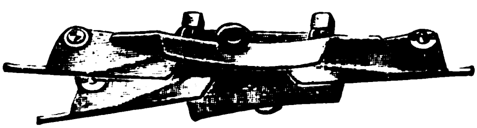
"Ajax" Line Section Switch—Open and Closed.

Mr. Blackwell and Mr. Dawson.

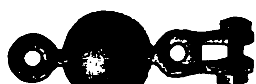
This device is strong and durable. The wooden piece between the terminals is renewable, and can be changed while on the line. A convenient clamping device renders it possible to leave enough trolley wire coiled on top of the section insulator to allow of its being let out to repair the line in case of a break.

Another part of this combination clamp holds the feed wire in such a way as to obviate the necessity of stripping the insulation from the wire, except at the part held by the clamp. By this arrangement the feed wire is left insulated from the poles to the section insulators, and between the lines (where there is a double track).

Two-Way Aerial Frog.

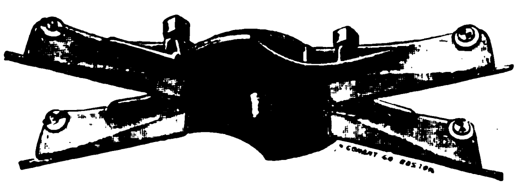


Two-Way Aerial Frog. (Straight under-running.)



"Globe" Frog Pull-off.

A number of frogs and crossings are on the table, and you can see how greatly the later types are improved over those used a year or two ago. All the newest styles have the "straight under-"running" feature, and require no solder, the trolley wire being clamped into the casting. You see that in all cases the trolley



Diagonal Crossing. (Straight under-running.)

wire is carried *over* the casting, so that the excessive wear at these points is taken by the heavy metallic flanges, and not by the

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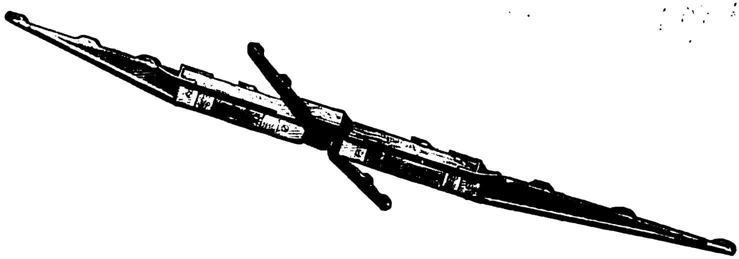
conductor. Right- and left-hand, "Y," and three-way frogs are used, and they are insulated and supported by frog pull-offs

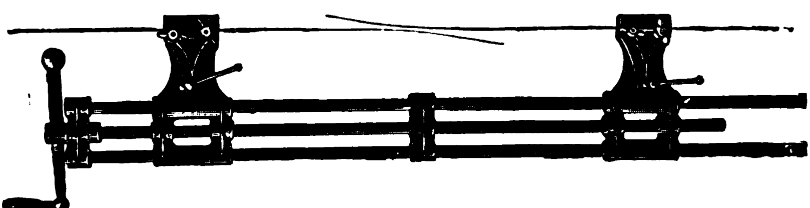
Right Angle Crossing. (Straight under-running.)

The operation of right and acute angle crossings is easily understood, and an insulated crossing is employed whenever one trolley wire crosses another from which it must be insulated.



Insulated Trolley Wire Crossing.

The wire-stretching machine shown is an extremely useful tool in all cases where it is necessary to take the tension off the trolley wire, as in splicing, or inserting switches, frogs, &c.

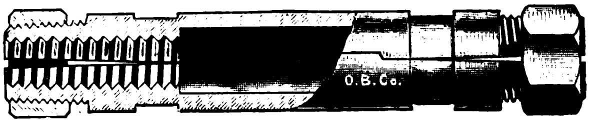


Wire-Stretching Machine.

Where overhead feeders are used, the practice of nearly all large American electric railways is to use a 500,000 circular mils, 61-wire strand, three-braid weatherproof cable, similar to this exhibit. The weight is from 9,800 to 10,000 lbs. to the mile.

Similar stranded feeder cables are used whenever the needs of

a line exceed 4/0 (B. & S.). The latter is used, either in solid or stranded form, by the great majority of lines outside the great cities. Below 4/0, solid wire is almost invariably employed. A feeder wire splicer is also shown. Mr. Blackwell and Mr. Dawson.



Feeder Wire Splicer.

This can be used as a permanent or temporary connector. The halves of the splicer are placed over the abutting ends of the bare wire. The nut is then screwed on the tapered end of the splicer, which is slightly corrugated on the inside, thus securely clamping the wire. If a permanent splice is desired, solder can be poured through a slot provided for this purpose. A joint made in this way is but a trifle larger than the wire, and is of low resistance and great strength.

Several styles of feeder insulators are shown. The best has a metallic yoke into which the feeder cable is laid and firmly held by a screw cap. This greatly economises labour in the erection of an aerial feed wire. Where guard wires are used, they are insulated by small porcelain insulators. The utility of guard wires is extremely doubtful, and many lines have discarded them. On the Continent, a strip of wood is often attached to the upper side of the trolley wire, whenever any danger from falling telegraph or telephone wires is apprehended.

"Ætna" Brass Cap Feeder Insulator

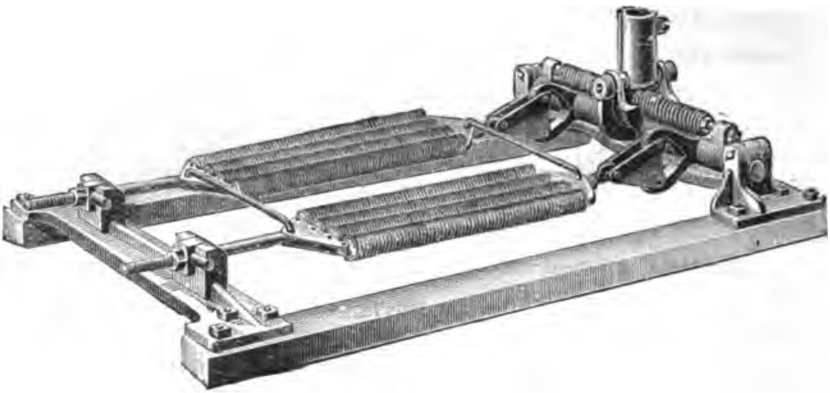
A number of special tools and appliances are on the table, to which we will not refer at length. They are self-explanatory, and we should be glad to have you examine them.

The trolley itself next claims our attention.

As in the case of all electric tramway supplies, the earlier types were comparatively clumsy, and the old form of trolley base occupied a great deal too much room on the roof of the car. It is shown in an illustration.

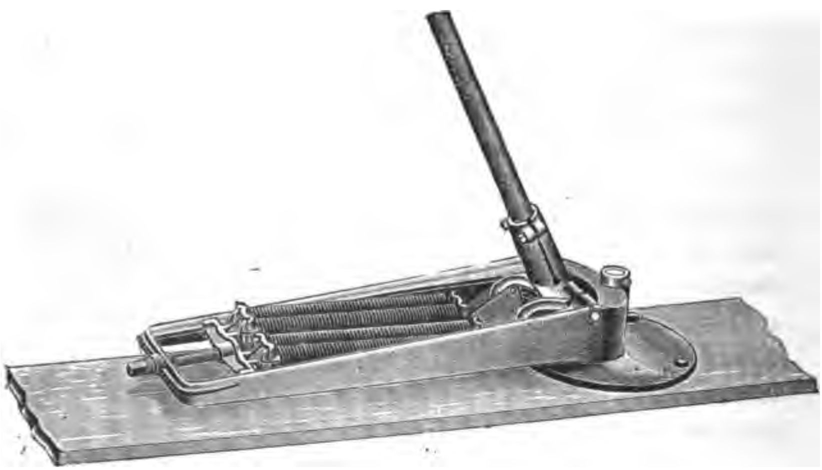
Mr. Blackwell and Mr. Dawson

The latest "Boston pivotal" type is fixed to the table. You note how easily the trolley moves in every direction.



Old-Style Trolley Base.

This base is of simple construction — neat, compact, and designed to allow of passing under low bridges. Experience has



"Boston Pivotal" Trolley Base.

proved it to be smooth-running, easy of adjustment, strong, and durable. It lies close to roof of car, and can be swung around to change direction. With pole laid down flat, the highest point on the base is but six inches above the roof. To avoid overtaxing the springs so that they will set or break, a very large safety factor is allowed. A special construction ensures an even

pressure of the wheel against the trolley wire in the different positions. This trolley received the highest award at the World's Columbian Exposition at Chicago. Mr. Blackwell and Mr. Dawson.

The steel trolley pole is of one piece of steel with a continuous taper, and without joints, shoulders, or other points of weakness. It is light, strong, and stiff. If bent by an accident, it can be straightened cold.

The steel trolley fork is of a new pattern, tapering in form, of sheet steel, light and strong, provided with phosphor-bronze contact springs and washers, which have proved far more durable than those of copper. The spindle is of hardened steel.

We are again indebted to Mr. Winslow for the loan of the Thomson-Houston trolley base, which is also fixed to the table. Its operation is practically the same as the other pivotal trolley, but you will see that the construction, especially as regards the arrangement of springs, is somewhat different.

"Boston Pivotal" Trolley, with pole *bent cold* to show strength of material.

Great attention has been paid to the development of a first-class trolley wheel, and several types are exhibited, showing the evolution of the present approved type now universally used.

Originally, when double-trolley wires were considered essential, a four-wheel truck was employed, and many were the troubles found in keeping it on the wires and in insulating one set of wheels from the other. The rudimentary under-running contact was a sliding shoe. This old pattern shows a somewhat elaborate contact on this principle. This wheel is an early attempt at a

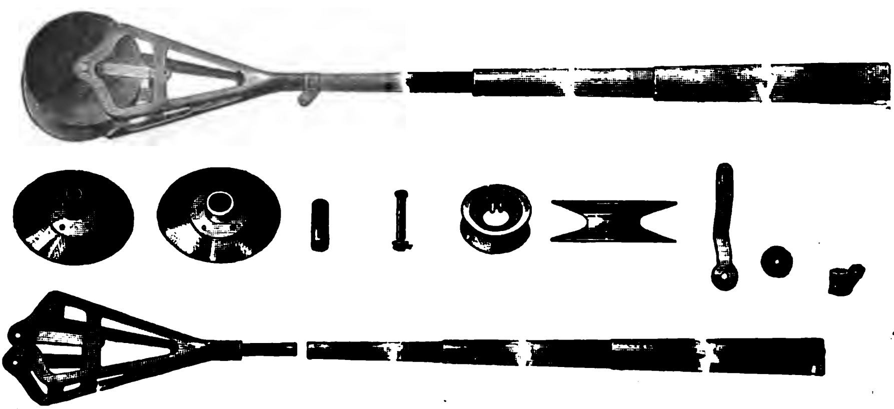
Mr. Blackwell and Mr Dawson.

rotary contact. It is interesting to note the wear. This is a later, though still an early, form of wheel, made, as you will see, of a single bronze casting, and with the V-shaped groove then considered best. A substantial improvement was made upon the earlier form, in the "Boston" wheel before you. In this a very substantial hub was provided to take the spindle. Iron guard plates were riveted on either side to prevent the trolley jumping the wire. The wear was taken by a contact ring which could be removed and replaced as needed, but at considerable expenditure of time and trouble. You will see how the shape of the groove has changed.

Spoked wheels are now universally used, like this "West End" wheel. These are made of a single bronze casting, having a wide and highly polished groove, and being furnished with either graphite or self-oiling bushings to receive the spindle.

When the older form of brass trolley wheel is used, the flange drops off when the groove which receives the trolley wire wears through to the outside.

By using the "spoked" trolley wheel this difficulty is entirely obviated by a simple and effective method of construction.



Old-Style Trolley Wheels and Trolley Pole-Head.

The ribs serve to hold the flange in position after the sparking of the wheel indicates that it is worn through, and therefore should be discarded. This warning is timely, for the wheel may be used after the flange is cut through by the trolley wire long

Mr. Blackwell and Mr. Dawson.

enough to get to the car house, where a new wheel can be put in. With the old form of brass wheel, when the flange wore through and dropped off, the car was disabled, and had to be pulled to the car house or removed from the track.

Modern "West End" Self-Oiling Trolley Wheel aud Pole-Head

If this breakdown occurs in a crowded thoroughfare, or in an out-of-the-way place where it is not easy to obtain assistance, as is often the case, the awkwardness of the situation and the annoyance resulting from it are obviously great.

You can see how thoroughly these ribs fulfil their mission by inspecting this "West End" wheel, which has run about 4,000 miles upon an English line.

A great deal of care has lately been devoted to the elaboration of a trolley more suitable for use with the English top-seat car than any of the American types shown. We had hoped to exhibit such an appliance, but although one is on the way to London it has not yet reached us. It may be exhibited at a later meeting.

This is the trolley head and wheel now employed by the Guernsey electric line. The wooden section is employed to insulate the iron trolley pole from the contact wheel. As this line uses roof-seat cars, it is indispensable for the comfort of passengers that the pole and base be insulated from the trolley wire.

Although the device is a somewhat rough-and-ready one, it works very well. We are glad to be able to say, from personal

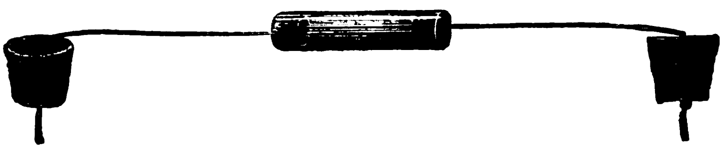
Mr. Blackwell and Mr. Dawson.

knowledge, that this Guernsey line is a thorough financial success.

We regret that we have been unable to secure for exhibition one of the trolleys of the South Staffordshire line.

The old style of lightning arrester, composed of copper discs separated by mica sheets, proved ineffective, because, when the line was struck by lightning and the discharge found its way across the insulated copper discs to earth, it frequently happened that, instead of the arc being broken by the small air spaces, it fused together the copper discs and thus formed a short-circuit on the line. Consequently, the lightning arrester had to be taken out of the motor circuit to prevent an abnormally high current discharge rate at the generators in the power house, —thus leaving the motors unprotected in case of a second lightning discharge, or else keeping up a heavy short-circuit until a new lightning arrester had been procured and inserted in parallel with the motor circuit.

One of the most interesting appliances to which your attention is directed to-night is this "Ajax" lightning arrester. The



"Ajax" Lightning Arrester Fuse.

rest of the apparatus is merely a support for holding a succession of these fuses, so that one after another is brought into operative position automatically by the action of the current as it consumes each fuse in turn.

The fuse consists of two pieces of No. 26 brass wire, each 3 inches long, having a single silk insulation, and lying side by side for about 1 inch, as do consecutive coils in an armature. This 1-inch lap of the wires offers abundant surface for the discharge gap, which is formed by the two thicknesses of silk, and amounts to little more than 0·002 of an inch.

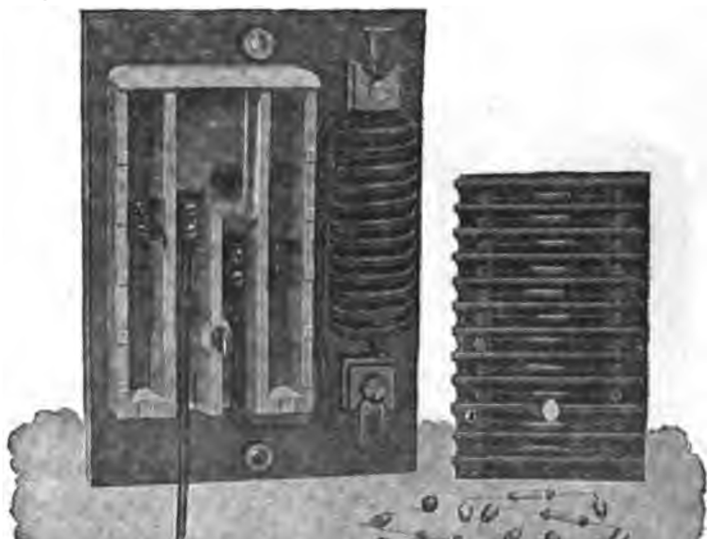
Small pellets of a highly insulating wax secure these wires in the above position, and a small glass tube is hermetically

sealed over this part of the fuse to keep the dischargers clean and dry until used. Mr. Blackwell and Mr. Dawson.

The extreme sensitiveness of this part of the apparatus is made possible by its being called upon to act but once.

The soft rubber plugs serve to hold the fuse in the corrugated cover of the arrester, and the bare ends of the wires project through the cover, ready to be brought into contact with the line and ground terminals.

This is the type of arrester used for protecting stationary motors or isolated plants. The regular size is made with a 100-ampere coil, having coil and arrester mounted on a marble slab $7\frac{3}{4}$ inches × 11 inches × $\frac{7}{8}$ inches.



"Ajax" Lightning Arrester for Isolated Plants or Motor Cars.
(Casing removed.)

Pole boxes are cast iron, asbestos lined, and so constructed as to exclude rain.

This is the more general form of pole arrester. In this the choke coil is contained in the arrester box; but it may be made by turning the insulated span wire on itself a sufficient number of times to make the choke coil, thus making a cheaper construction and a smaller pole box.

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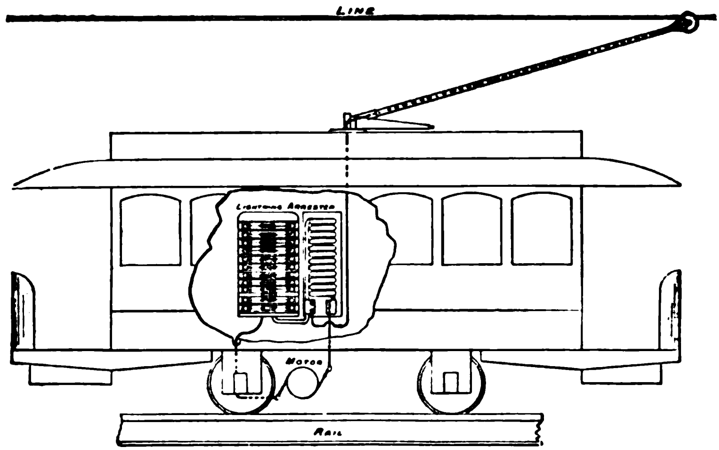
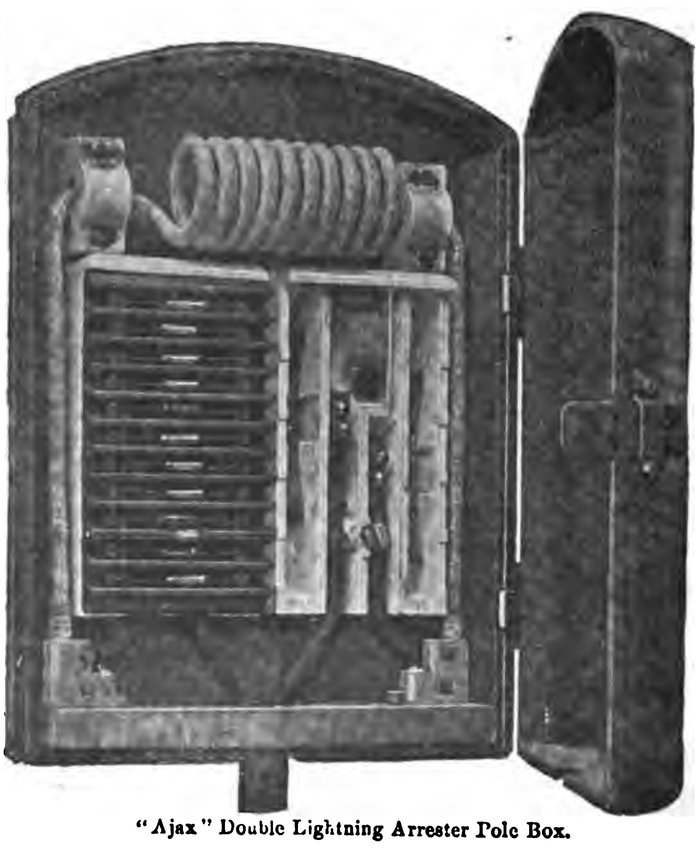


Diagram of Connections of "Ajax" Motor-Car Lightning Arrester.



"Ajax" Double Lightning Arrester Pole Box.

Mr Blackwell and Mr Dawson.

The warming of tramway cars by means of electric heaters is now universal in America wherever the climate is at all cold. This is the simplest form, of which any number desired may be screwed under the seats of a car. More elaborate forms are also made.

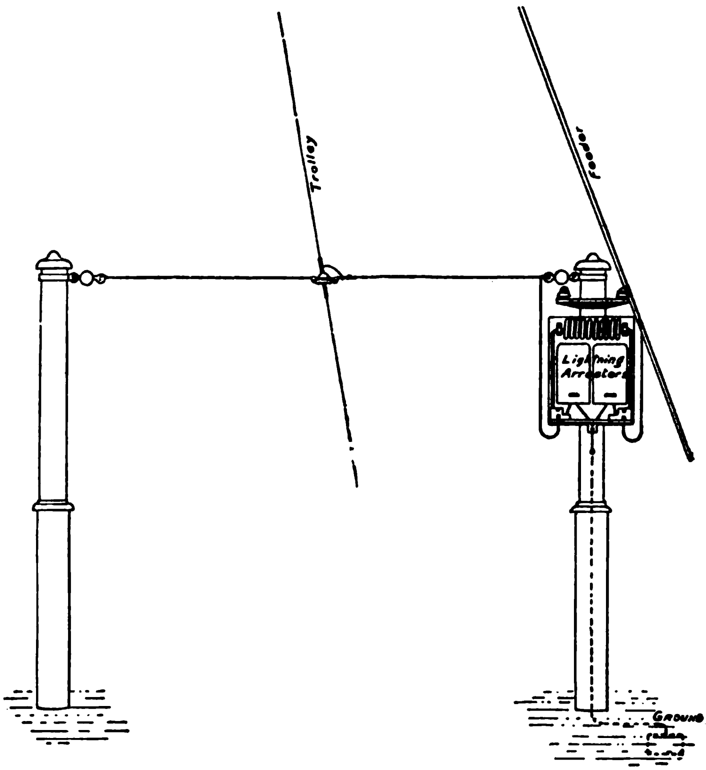


Diagram of Connections of "Ajax" Pole Lightning Arrester.

A word may be said in support of what Mr. Wilkinson has said as regards the appearance of overhead conductors. Undoubtedly some aerial lines have been put up with an utter disregard of appearances, and inexperienced or careless constructors have erected webs of trolley, strain, and feeder wires which were most obnoxious. This is especially true of many hastily built American lines, pushed through at high pressure, and at the smallest possible expenditure. Now that the first rush is over, and the tramway operator, the manufacturer, and the contractor

Mr. Blackwell and Mr. Dawson. have had time to take breath, the weight of public and Press criticism has had its effect, and no pains is spared to perfect the entire plant and apparatus.

A carefully designed and erected line, with sub-surface feeders, handsome poles, &c., has but few objectionable features; and in the great majority of cases public convenience is so greatly enhanced by the overwhelming advantages that closely follow upon the introduction of improved and more rapid transit facilities, that opposition to the extension of a trolley line is almost unknown.

The Siemens line at Guernsey,—the line that crosses the great piazza on which Milan Cathedral stands,—the Brussels, Hamburg, Bremen, and a dozen other Continental installations,—are European examples of line construction to which no reasonable objection can be urged. The electric tramway has a future as great in Great Britain as elsewhere, and in no other country in the world has it failed to already secure universal acceptance.

The English tramway operators, and the able executive officers of the Tramways Institute of Great Britain and Ireland, are keenly alive to the possibilities that lie in electric traction, and, under most adverse conditions, are doing their best to smooth the path of progress. It remains with you, gentlemen, to supplement their endeavours, and to do your best to stimulate and encourage the growth of public opinion in its favour.

The President. The PRESIDENT: Gentlemen,—I suppose I am doing right in thanking Mr. Blackwell and Mr. Dawson very much for their paper, and for the very interesting collection of tramway appliances which they have brought here for your inspection. At this time of the evening it is, of course, impossible to begin the discussion on these papers, which must therefore be postponed until our next meeting. I accordingly adjourn this meeting until November 22nd.

The meeting then adjourned.

The Two Hundred and Sixty-eighth Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, November 22nd, 1894—Mr. Alexander Siemens, M. Inst. C.E., President, in the Chair.

The minutes of the Ordinary General Meeting held on November 8th, 1894, were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

Messrs. J. T. Morris and J. O. Girdlestone were appointed scrutineers of the ballot for new members.

The President: I am sorry to say I have to announce the death of an old member of the Institution who has had a great deal to do with the development of the submarine defences—Colonel Armstrong, R.E., who died not very long ago. A great many of us have come in contact with him. Besides developing the system of submarine mining, he was the first electrical adviser to the Board of Trade. I bring this to your knowledge, and suggest that we should express our sorrow at Colonel Armstrong's death.

Donations to the Library were announced as having been received since the last meeting from the Director-General of Telegraphs, India; Dr. J. A. Fleming, H. Laws Webb, and C. H. Wordingham, Members; to whom the thanks of the meeting were duly accorded.

The President: I will now call upon Dr. du Riche Preller to read a paper on a kindred subject to that on which papers were read on the last occasion.

ELECTRICAL STEEP-GRADE TRACTION IN EUROPE.

By C. S. Du Riche Preller, M.A., Ph.D., A.M. Inst. C.E., Member.

Introduction.

Dr. Preller. The rapid growth of electrical traction in Europe, wherever local conditions and reasonable official regulations are conducive to its adoption, is evidenced by the fact that within the last few years it has also been extensively applied, and is in course of further application, on steep-grade or mountain railways properly speaking—that is, on lines which have not only occasional steep-grade sections, such as occur, for instance, on many electrical tramways, but continuous gradients varying from 5 to 25 and upwards of 60 per cent. (1 in 20, 1 in 4, and 1 in 1·6 respectively), and which connect either the base and summit of a given declivity, or different districts separated by a mountain range.

It will, therefore, not be inopportune if I place before the Institution a short synopsis of what has been already done in Europe in that branch of electrical engineering, together with certain conclusions and proposals founded on my own experience.

Leaving aside for the present, as being more suitable for separate and subsequent treatment, the question of heavy—viz., 50- to 100-ton—electrical locomotives for trunk railways, the working of steep grades by electricity may be considered under two heads—

1. By Cable Traction; and,
2. By Motor Cars or Locomotives with Fixed Conductors.

Cable Traction.

Up to a recent period, steep-grade cable railways in various parts of the globe, but notably in Switzerland and in the Alps generally, where they alone exceed 20 in number, have been constructed for being worked either by component of gravity with water ballast, in conjunction, on some lines, with a second or compensation cable, or in some cases by fixed hydraulic, gas, or steam motors

The principal disadvantage common to all lines worked by component of gravity consists in the excessive additional dead load due to the water ballast, which entails not only a great deal of additional brake power *per se*, but a variety of complicated safety brakes, involving very careful manipulation; while the three systems of fixed motors are either uneconomical, or unwieldy and obsolete. Dr. Preller.

The superior advantages of cable traction by electrical motors, as compared with all the other systems referred to, have been attested by three lines in Switzerland, all of which have been constructed within the last four or five years—to wit, the Burgenstock, on the Lake of Lucerne; the Monte Salvatore, on the Lake of Lugano; and the Stanserhorn, near the Lake of Lucerne, which last named was opened for traffic only last year. It is not the purpose of this paper to give a detailed description of these lines; suffice it to point out their salient, and more especially their electrical features.

(*a.*) *Burgenstock.*—The summit level of this line is 2,884 feet above the sea, the total rise being 1,443 feet in a little over 1,000 yards, the minimum grade 32, and the maximum 58 per cent. Electric motive power for working the cable and cars is obtained by high-tension (1,600-volt) transmission from a 300-H.P. hydro-electric power station 2·5 miles distant, the output of the two series-coupled direct-current Thury dynamos, driven by a high-pressure turbine, being 40 kilowatts, or 60 H.P. Two corresponding series-coupled motors at the summit of the cable railway drive the cable winding drum through belt, countershaft, and bevel gearing; the total reduction being 700 to 5 revolutions, or 140 to 1, corresponding to the regulation car speed of about three miles per hour. The car speed is regulated from the motor station, and not by the driver, except in case of emergency.

(*b.*) *Monte Salvatore.*—This line has a summit level of 2,900 feet, the rise being 2,000 feet in a length of 1·2 mile, the initial grade at the base 17, and the maximum at the summit 60 per cent. The motor station is situated midway up the incline, and the power is derived by a 2000-volt transmission from a large hydro-electric 1,500-H.P. power station five miles distant; the

Dr. Preller. output of the Œrlikon (Brown) direct-current generator, driven by a high-pressure turbine, being 60 kilowatts. The corresponding motor on the line drives the cars and cable in precisely the same way as on the preceding line, except that the Salvatore incline is worked in two sections.

(*c.*) *Stanserhorn.*—This line ascends an altitude of no less than 6,200 feet above sea level, and has a total rise of 4,570 feet in a length of 2·5 miles, worked in three sections, having maximum gradients of 30, 60, and 62 per cent. respectively. The requisite power per car is 40 H.P., and a motor station is placed at the summit of each section. The three Thury motors actuate the winding drums as before described, and are fed from the same power station as the Burgenstock line, but by a separate high-tension (2,000-volt) transmission 2·5 miles in length. The total efficiency on this, as on the other lines, is about 60 per cent.

(*d.*) *Conclusions.*—The three lines of which I have given a necessarily very incomplete *resumé* mark a conspicuous advance in cable traction. As compared with haulage by the other systems referred to, they show a saving in car weight of no less than 50 per cent., the full car load with 36 passengers being in the former case 12 to 15 tons, and on the electrically worked lines only 6 to 7 tons. Again, the average cost of construction of the Swiss cable railways worked on the older systems is no less than £41,000 per mile, whilst that of the electrical lines is only £24,000 per mile, or 40 per cent. less. Similarly, the working expenses on the older lines vary, with one or two exceptions, between 60 and 80 per cent., whereas the electrical lines are worked at 45 per cent. of the receipts, the total average working cost being 4s. per car mile. These three lines also show a remarkable development due to electrical traction *per se*, inasmuch as, apart from the unprecedented grades, up to 62 per cent., or 1 in 1·6, the length of the incline has been gradually increased from 1,000 to 2,200 and 4,500 yards, which, having regard to the mechanical work performed on the grades, is equivalent to 14, 20, and 44 miles respectively on the straight and level. And, lastly, the superior safety, simplicity, and smoothness of electrical working, attested by the Burgenstock and Salvatore lines, has made it possible to dispense

on the Stanserhorn incline with the rack used as a safety factor on its two predecessors; so that on Stanserhorn electrical traction has achieved the feat of scaling Alpine altitudes which, it was hitherto believed, could only be reached by rack railways worked with special steam locomotives, such as those used on the 48 per cent. grades of the neighbouring Mount Pilatus line, at double the expenditure of power, double the train load, and more than double the cost per train mile. Dr. Preller.

Traction by Motor Cars or Locomotives with Fixed Conductors.

The first steep-grade railway worked by electrical traction with fixed conductors in Europe was the Florence and Fiesole line, opened in 1891. It was in succession followed by the Murren mountain railway, in Switzerland, opposite the Jungfrau; by the Mont Salève line, in Savoy (near Geneva); by the Genoa, and then by the Zurich steep-grade road railways; and quite recently by a similar line at Barmen, in Rhenish Prussia.

Of these lines, those of Florence, Murren, Genoa, and Zurich have continuous grades of 8, 5, 7, and 6 per cent. respectively, and are worked as simple adhesion lines, with overhead contact wires, and return circuit by the electrically bonded rails; while the Salève and Barmen lines, having continuous inclines of 25 and 18 per cent., or 1 in 4 and 1 in 6 respectively, are worked with the aid of a rack, and the former has an outside conductor rail in the shape of an inverted ordinary flange rail, while the latter has overhead contact. The Murren line is the only one worked with electrical locomotives; all the others are worked by single motor cars.

(*a.*) At *Florence*, the power station, situated at the foot of the incline, comprises three Tosi boilers, three Œrlikon vertical compound 90-H.P. engines, and three belt-driven Edison bipolar dynamos with a total effective power of 245 H.P., equal to 93 per cent. efficiency. The 12 motor cars are each fitted with two 20-H.P. spring-suspended and series-coupled Sprague-Edison motors, the original ones having double-reduction, the more recent ones single-reduction spur gearing. The contact is

Dr. Preller. by trolley wheel and pole, and the total efficiency of the system is 66 per cent.

(*b.*) On the *Murren* railway, whose altitude is 5,300 feet above sea level, power is generated by a high-pressure turbine, which drives a direct-coupled Œrlikon (Brown) bipolar dynamo of 120 H.P. The power station is situated about midway of the line, the power being derived from the torrent of the celebrated Staubbach Fall. The four locomotives weigh 7·5 tons each, and carry two 30-H.P. single-reduction spur-geared motors; the tractive force of each locomotive being about one-third of its weight – sufficient to have two saloon cars (15 tons) on the 1 in 20 grades at a speed of eight miles per hour. The total efficiency of the system is 68 per cent.

(*c.*) The power station of the *Mont Salève* line (summit level, 3,700 feet above the sea) is situated about a mile from the line, and comprises two low-pressure turbines and two separately excited Thury multipolar dynamos mounted on the vertical turbine shafts, and giving, at the low turbine speed of 50 revolutions per minute, 500 H.P., or only a quarter of their combined normal output of 2,000 H.P. The 12 motor cars are each fitted with two 30-H.P. four-pole Thury motors, with double spur gear reduction, and current is taken from the outside conductor rail by metallic slide-contact shoes. Owing chiefly to the unnecessarily heavy gearing of the motors, the total efficiency is only about 52 per cent.

(*d.*) At *Genoa*, the power station is about 1·3 mile distant from the line, and contains at present two boilers, two compound condensing Tosi 160-H.P. engines, and two belt-driven 110-kilowatt Siemens inner-pole dynamos. The present line, which is the nucleus of a projected suburban system, is worked by six cars, each fitted with two 16-H.P. Siemens motors; the reduction being 10 to 1, by chain and toothed wheel. Current is taken from the overhead wire by two Siemens & Halske's rectangular metallic contact frames.

(*e.*) The *Zurich* power station is placed at the upper end of the line, and comprises two Galloway boilers, two 100-H.P. Œrlikon vertical engines and dynamos, together with an accumulator

battery of 300 Tudor cells for compensating the variations of load Dr. Preller.
of the steam engine. The 12 motor cars are each fitted with two 12-H.P. Œrlikon motors. The total efficiency of the line is 65 per cent.

(*f.*) At *Barmen*, the power station is situated at the foot of the incline, and contains two 225-H.P. compound condensing engines driving direct two Siemens inner-pole ring dynamos, whose output is 155 kilowatts each. The line is worked by 10 motor cars, each provided with two 36-H.P. Siemens motors, which, by single spur gearing, actuate the rack pinions mounted direct on the car axles. The total efficiency is, like that of the other lines, from 60 to 65 per cent. It is hardly necessary to add that the working tension in all these cases is 500 to 600 volts.

(*g.*) *Conclusions.*—It is seen that the primary generating power is steam on the Florence, Genoa, Zurich, and Barmen, and hydraulic on the Murren and Mont Salève lines; the dynamos being direct-driven in four, and indirect in the other two cases. Notwithstanding the high cost of fuel in Italy and Switzerland (as much as 30s. per ton), and the steep grades on the Florence, Genoa, and Zurich lines, the traction, traffic, and maintenance expenses do not exceed 4·5 pence per car mile; while the total working expenses, including administration and renewals, are within 7·5 pence per car mile, or about 50 per cent. of the receipts. On the Murren and Salève lines, the cost of hydraulic power per annum is, of course, restricted to wages and repairs. In the former case, the working expenses do not exceed 40 per cent. of the receipts; while in the latter they are as much as 80 per cent., this high rate being due chiefly to inadequate fares, and therefore no proper criterion. The Salève and Barmen rack lines are worked at a total expenditure of about 3s. per car mile. A specially noteworthy feature is the steady speed of 8 to 10 miles per hour with which motor cars run up the steep adhesion inclines of 6, 7, and 8 per cent. at Zurich, Genoa, and Florence; while on the descent a speed of even 15 miles per hour has proved perfectly safe, in conjunction with the powerful and instantaneous action of the electric safety brake constituted by the motors acting as dynamos on the descent,

Dr. Preller. although, for all ordinary purposes, even the mechanical brake alone suffices to stop the car within its own length.

As regards the comparative working cost of steep-grade adhesion or rack railways by steam and by electricity, I can affirm from my own experience, as well as from every other case which I have had occasion to investigate, that, irrespective of the immensely greater elasticity of the service, and consequently the far more rapid development of the traffic, electrical working ensures an economy of at least 50 per cent. as compared with steam.

In face of this fact, it may safely be averred that the conversion of the numerous steam-worked mountain railways of the well-known Righi type in the Alps and in other parts of Europe to electrical traction is simply a question of time; and that in this country, too, the projected lines of a similar character, such as those of Snowdon, Ben Nevis, and Arthur's Seat, will and can be economically worked only by electricity. And the same may be said of ordinary adhesion lines, notably tram roads, with steep gradients ranging from 5 to 8 and up to 10 per cent., such as are by no means peculiar to the Continental lines I have described, but are met with both in towns and on country roads in many parts of the British Isles.

General Conclusions.

With regard to electrical traction on flat, as well as steep-grade lines generally, I am led to the following conclusions:—

Direct and Indirect Driving of Generators.—Although direct driving, whether by steam engines or by turbines, is the ideal standard, and therefore always desirable and preferable, it cannot, for tractive purposes, be laid down in all cases as a dictum *à priori*. On lines having steep, and more especially alternately rising and falling grades coinciding with sharp curves, an intermittent traffic, and frequent stoppages, the fluctuations of load are so great and so rapid—often from zero to maximum, and *vice versâ*, in the space of one minute—that vertical high-speed engines, more especially small units, generally work very uneconomically. This is, *e.g.*, the case at Florence, and in an

even greater degree at Marseilles, where the high-speed direct-driving engines had actually to be replaced by horizontal low-speed Corliss engines, with belt driving. In the case of hydraulic power, high-pressure turbines always admit of economical direct driving, whereas low-pressure turbines involve for direct driving proportionately larger dynamos, giving only part of their normal output, so that here, too, indirect driving by gearing or belt is generally more economical. The same applies where gas engines are used. Dr. Preller.

Steam, Hydraulic, and Gas Generating Power.—The first cost of an hydro-electric installation often exceeds that of steam plant, being in some cases as much as £60 per H.P., more especially in the case of a variable volume and small head of water, involving the use of low-pressure turbines and extensive canalisation. High-pressure turbine installations are always preferable and more economical, both as regards first cost and working efficiency. Where cheap hydraulic power is not available within a distance of about four miles from the line, or electric motive power cannot be hired at £4 to £6 per H.P. per annum, and where fuel is dear, gas manufactured on the spot is much more economical than steam power.

Conductivity of Rails.—Where the rails serve as return circuit, the ordinary fish-plates should have the same sectional area as the rails, so that, together with stout fastenings, they make a joint as stiff as the rail itself. In this way, and especially when laid on metallic sleepers, as is practicable with overhead contact, the permanent way gives 80 per cent. of the required conductivity at the joints; so that only 20 per cent. has to be made up by copper bonding, *plus* an adequate margin of, say, 10 per cent. By this means the average loss of tension on the line does not exceed 1 per cent. per mile. Solidity, compactness, and careful maintenance of permanent way, such as is usually found on electrical lines, as well as on railways generally in Europe, go far to make up for the elaborate copper bonding which the often defective condition of permanent way necessitates on American lines. It is for the same reason that electrolytic action on gas and water pipes, which is so common a phenomenon in the States, is practically unknown in Europe.

Dr. Preller. *Conductor Rail.*—Where a conductor rail is used, it should preferably be placed outside, instead of inside the ordinary rails, because the outside conductor obviates all complications, and the contingency of short-circuit at points and crossings. On specially steep grades, involving the use of a central rack, the rack rail or bar itself, having continuous contact with the pinion wheels, constitutes an excellent conductor, provided it be effectually insulated from the sleepers by porcelain bells serving as supports. In both cases, and provided metallic cross sleepers be used, the conductor rail has the advantage that any leakage passes, not to earth, but into the ordinary permanent way as return circuit.

Overhead Trolley Wheel and Slide Contact.—Contact by a trolley wheel whose spindle is rigidly held by the trolley pole is suitable for lines on which straight sections and flat curves predominate; but for lines with numerous and sharp curves, the rectangular single or double slide-contact frame, as used by Messrs. Siemens & Halske on their overhead lines, is far preferable. It is lighter and more pleasing in appearance than either the rigid trolley, the flexible South Staffordshire trolley, or the slide-contact bars used on the Isle of Man line. It obviates, moreover, many of the objectionable cross and diagonal wires, and hence the infinite variety and complexity of fastenings which the use of the rigid trolley wheel involves, and many of which, however neat as mechanical contrivances *per se*, are not exactly ornamental objects when suspended at a height of only 20 feet above the roadway. The only defect to which the Siemens slide contact is subject consists in the upper, slightly arched, and, of course, renewable contact side of the frame being liable to become grooved, whereby the easy play to right and left of the contact wire is impaired; but this defect can be easily remedied by employing material of adequate resistance. This contact system is used on the Buda-Pesth suburban lines, as well as at Dresden, Hanover, Mulhouse, on the Barmen and Genoa lines already mentioned, and, in a modified form, necessitated by the cars having outside seats, also at Hobart Town. Another and very simple form of slide contact is that used on an electric road railway from the Lake of Lucerne to the foot of Stanserhorn, and con-

sisting in a crescent-shaped grooved contact piece of bronze, which is loosely hinged to the trolley pole, and thus, in conjunction with the lateral play of the pole, adjusts itself to the sinuosities of the line. Dr Preller.

Underground Contact and Accumulator Cars.—It is generally recognised that the overhead trolley system, which, much as it has been improved, is in reality only a makeshift, is unsuited for the central parts of the large towns, and, *à fortiori*, of the metropolis of this country; and the same applies equally to the other largest capitals of Europe—to wit, Paris, Berlin, and Vienna. In these cases, the conduit system or accumulator cars are therefore at present the only practicable solution of the problem. In Europe, the conduit system, whether it be that of Buda-Pesth, or with a central slot, may be estimated to cost complete at least £10,000 per mile of single line and upwards, according to local conditions, though this is not too costly, having regard to the enormous traffic in large towns; but its efficient working presupposes, among other things, very perfect drainage of the trench. As regards accumulator cars, they would really constitute an ideal form of electrical tramway traction in towns, if the present car weight of 12 to 15 tons, and the power and traction expenses of 8d. to 10d. per car mile, could be reduced to half. As a case in point may be quoted the unwieldy accumulator cars which run on the Madeleine and St. Denis Tramway in Paris, and give fairly satisfactory results, but which, owing to their heavy weight, are not infrequently deficient in torque on the long 1 in 20 grades, when the motors become saturated. Moreover, as at present constituted, electric accumulator cars have a formidable rival in another, and absolutely smooth and noiseless, though equally costly, form of storage system, viz., that of compressed air, as used at Nantes, at Nogent, in the suburbs of Paris, and at Berne, in Switzerland. The overhead system, on the other hand, is very well adapted for suburban tramways, and eminently so for light railways and road railways in the country. The cost of such suburban street railways is about £15,000 per mile of double line, including equipment; while that of road railways in country districts, if constructed on the metre or

Dr. Preller. 3 ft. 3 in. gauge, can well be kept within £6,000 per mile, including electrical equipment. In this connection, the already quoted road railway from the Lake of Lucerne to the foot of Stanserhorn, which only cost £4,500 per mile, as well as another similar line near Bâle worked with locomotives, have demonstrated what a cheap and convenient electrical service can do in essentially agricultural districts.

Gearless and Geared Motors.—Gearless motors are eminently suitable for high speeds, while for low speeds they require to be of inconveniently large size. For geared motors single reduction is of course always preferable, although on exceptionally steep grades, where the motors have to develop their maximum power at minimum car speed, double reduction may in some cases be unavoidable. In any case, spur gearing is always preferable to worm gearing or chain motion, both of which involve too much friction and consequent loss of power.

Parallel and Series Coupling of Motors.—This much-debated question cannot be decided *à priori*, but depends on individual cases. For level or easy-grade lines, parallel coupling is more suitable; whereas on steep grades, where starting requires always the maximum torque, series coupling is generally called for.

Variations of Load.—On lines with steep or rising and falling grades, these variations cannot be mitigated, much less equalised, simply by increasing the number of cars or trains on the line, since the variations are caused not only by the varying traffic, but by the varying grades and curves, and by the varying degrees of adhesion, more especially in starting. Where separately excited dynamos are used, a means of partially compensating the variations of load is, as is well known, that of varying the excitation by the main current passing through the exciter. Another partial remedy is that of Thury's automatic regulation by a shunt of the main current passing through a solenoid and acting on an armature which, in its turn, acts automatically on a rheostat. Or, again, in some power stations, so-called Raffard coupling discs are used, which act at once as fly-wheels and as a protection of the dynamos against short-circuit in case of atmospheric discharges. But all these devices are more or less palliatives, and more especially

automatic regulation, such as Thury's, is effectual only when the Dr. Preller. speed of the steam engine or turbine is constant. The most effectual remedy is the addition to the power station of an accumulator battery, which absorbs any excess of supply from the generator over demand on the line, and, *vice versâ*, makes up for any deficiency of supply, so that the steam engine and generator—viz., the unit or units required for the ordinary service —can always run at full and constant load. Accumulator batteries have fully vindicated their claim as an important auxiliary and as a means of economical working of traction installations at Zurich, and still more recently in the Isle of Man, and well repay the additional first cost of plant, seeing that the saving in fuel alone suffices to cover the first cost of the battery in three or four years.

Accidents.—In Europe, the tramways and railways so far worked by electricity, and aggregating about 500 miles in length, have hitherto practically enjoyed immunity from serious accident to human life. The only serious case was that which occurred on the Florence and Fiesola line shortly after the opening for traffic, when a totally incompetent driver completely lost control over the more than sufficiently powerful mechanical and electric brakes of a full car, which, running unimpeded down the 8 per cent. incline, attained a velocity of 40 miles per hour, and left the metals on entering a sharp curve, precisely at the point where the centrifugal force exceeded the car weight, the result being the loss of five lives. This accident taught the salutary lesson that in Europe the safety of the service and that of passengers imperatively require the driving of electrical cars or trains by properly trained and competent men.

Continuous and Alternate Current.—Hitherto continuous current has been exclusively used for electrical traction. But, having regard to the high degree of efficiency and perfection and the ease of starting recently attained in alternate-current motors, thanks notably to the persevering efforts of such constructors as Messrs. Brown, Boveri, & Co., it may be confidently predicted that, as in lighting installations and in power transmissions for industrial purposes, so also in electrical traction alternate is destined to supplant continuous current. Alternate current,

Dr. Preller. whether single or multiphase, will not only admit of electrical traction being applied over much longer distances than is economically possible with continuous current, but it will ensure a saving of something like 30 per cent. in the weight of dynamos and motors, irrespective of the saving in copper of feed and contact wires, and will thus considerably simplify and cheapen electrical installation and equipment for tractive purposes. But, whether by alternate or by direct current, or by a combination of both, on flat as on steep-grade lines, on so-called light railways as on tram roads in town and country, we may be well assured that electrical traction in its various forms has, both in this United Kingdom, in the Colonies, and throughout Europe, a brilliant and triumphant future.*

The PRESIDENT: After the way in which you have received this paper, I think it is hardly necessary to ask you to pass a formal vote of thanks to Dr. du Riche Preller. I will now call upon you to discuss Mr. Wilkinson's paper, which has already been printed in the Transactions, the two papers which we heard on the last occasion, and Dr. Preller's paper.

Dr. Keith. Dr. N. S. KEITH: I can add, for whatever interest it may be to the Institution, a short description of a plant in which a grade of 1,600 feet in 3,000 is ascended by means of electrical power, viz., that of the Pasadena and Mount Wilson Railroad, in Southern California. It has been built as a road to satisfy the pleasure-tourists who ascend into the high mountains from the hot climate of Pasadena in summer time, and to give them a diversion by carrying them into the snows in the winter, from places where they have no snow. The line runs from Pasadena, and will eventually end on the top of Mount Wilson, some 13 or 15 miles away, at an elevation of 7,000 feet above the sea. I am only giving approximate figures. The line was completed and inaugurated a year ago last July to the top of Echo Mountain—3,500 feet above the city of Pasadena, which is some few hundred feet above sea level. For a distance of two or three miles the average grade is a very uniform one, of about 7½ per cent. There s then a grade which necessitates an ascent of about 1,600 feet in 3,000. The ascent and descent are made by means of a cable

* For illustrations of Dr. Preller's paper see Plate C.

run by a 75-H.P. Keith electric motor, placed at the summit of the rise. There are two cars fixed at equal distances on the endless cable, so that when one runs up the other runs down, and thus balance each other. The cars are so constructed that the seats are horizontal; the inclination of the car base is approximately 45°. The motor receives its electric current of 500 volts from several sources. At a small town half-way between this severe rise and the town of Pasadena are located two 60-H.P. gas engines driving dynamos. At various localities in the mountains above are placed dynamos, driven by Pelton tangential water-wheels, which receive their impetus from small quantities of water under heads of several hundreds of feet, playing tangentially against radial buckets upon the wheels. This combination of gas engines and water-wheels is a present necessity, because the quantity of water now available for power is insufficient. It is in contemplation, and will be carried out by the time the road is completed to the top of Mount Wilson, to derive a quantity of water from the other side of the mountain. Four hundred feet below the summit there is a small stream flowing. It is in contemplation to pump this water over the 400 feet by electrical power, and allow it to fall upon the western slope of the mountain, where it has in the course of a few miles a descent of 4,000 feet. Two hundred or 300 feet in excess of the 400 feet will give sufficient fall to furnish electrical energy for power to run the motor and pump, leaving some 3,300 feet fall for power for the direct work of the railway. Dr. Keith.

Mr. MARK ROBINSON: I should like to say a few words, not of criticism, but of appreciation and welcome to these valuable and important papers. Experts who speak later will deal as men of science with the scientific questions involved; I, who have no claim to speak upon this subject as an expert, will but say a few words upon the commercial aspect of these papers. Like many others in this room, my living is bound up, in part at least, in the expansion of the electrical industries of this country; and I believe these papers come at a most propitious time, and that they will give no small impulse to that expansion. Electric traction is upon us, and its coming magnitude but few of us are able to Mr. Robinson.

Mr. Robinson.

measure, but it will be greatly to the benefit of engineers and electricians, not less than of the capitalists who will build and of the public who will use the lines. Not forgetting much good work in Germany and in other Continental countries, and the really remarkable traction works which have been carried out in England, though, unfortunately, to such a limited extent, I think we must all allow that the country which has most to teach us in electrical traction is America. In the last session we had the recent general progress of electricity in America sketched for us with a master's hand by Mr. Preece; now we have a younger engineer who has utilised his stay in that country to bring back to us, in a form at once concise and attractive, much valuable information about the details of American practice. It should be gratifying to us that not only did our American friends place their experience and knowledge at Mr. Wilkinson's disposal as an individual, but they did so avowedly for the benefit of this Institution, for which Mr. Wilkinson told them that he desired information. It is perhaps even more gratifying that an American engineer lays before us fully, and, as far I can judge, without any reservation, not merely the general facts of American electric traction practice, but just those important details upon which success depends—the how to do it, and the how not to do it. The paper of Mr. Blackwell and Mr. Dawson is what I call an unselfish paper, and I think we ought to thank them very much for it. Their display of apparatus appeared so interesting that, having friends in France at the present time engaged upon a large electrical traction scheme already decided upon, we thought we could do them no better turn than ask them to come over and see it. They have seen it to-day, and are here now; and although, by reason of the curse of Babel, they cannot join in our discussion, they say they are rewarded for coming over from Paris by the interest of Mr. Blackwell's collection. One of those gentlemen is Mons. Heilmann, whose name is familiar amongst electricians and railway engineers alike; and with him is Mons. Mazen, one of the engineers of the Western Railway of France, upon whose line the Heilmann locomotive was tried this year, and upon whose line it is to be tried next year upon a far greater scale.

Dr. Preller's paper deals mainly with specialities, such as mountain railways, for which we have no great scope in this country, and I think we shall agree that the papers relating to American practice come more closely home to us than his. If anything would tempt me to indulge in criticism to-night (which I said I would not), or to trespass on the province of the experts, it would be some of the statements in Dr. Preller's paper There is one of a very striking kind in condemnation of the use of high-speed direct-coupled engines for electric tramway work; but I will refrain—consoled, however, by the fact that if that question needed discussion at all, it should have been discussed some years ago, for it is past discussion now. Mr. Robinson.

Mr. H. F. PARSHALL: I have listened to the papers on American tramways with particular interest, because I am desirous to learn whether any features peculiar to American tramways have been observed, and because my time has been considerably occupied in designing apparatus for their use since the first commercial electric tramways were begun in the United States. Mr. Parshall.

The subject of earth returns has been touched on in all the papers. I may say, with respect to this, that the troubles now so common in the United States might have been largely avoided had these return circuits been put in according to principles that are thoroughly well understood. The extent to which the rails may be utilised as a return circuit depends on how well they are electrically connected together. Ordinary fish-plates are of no use in accomplishing this. The rail-bond must carry the whole current from rail to rail. The contact between the bond and rail has been almost universally a pressure contact. Experience with polished copper pressure contacts is that a current-density of 300 amperes per square inch for currents up to 500 amperes should not be exceeded. For greater currents so high a density is not permissible, since the contact surfaces cannot be fitted so well together.

With iron contacts, especially when liable to corrosion, 50 amperes per square inch is as high as is safe in most cases. In other words, if 1,000 amperes per square inch is taken to be the mean current-density permissible in the bonds, the contact

Mr. Parshall.

surface between rail and bond should be 20 times the section of the bond. Supplementary conductors should be located so that the current-density in the bonds is kept within this limit. In the case of very large currents the permanency of the earth circuits is best insured by electrically welding all the joints together.

Mr. Wilkinson touched on the amount of power taken by electric tram-cars. Some further data may be appreciated.

A fair value for the amount of energy taken by ordinary cars of from 8,000 to 10,000 lbs., making schedule time from 8 to 12 miles per hour, is one Board of Trade unit per car mile, corresponding to from 60 to 80 lbs. of steam taken by high-speed American non-condensing engines and belt-driven dynamos used in small stations, or 35 to 40 lbs. of steam taken by slow-speed Corliss non-condensing direct-connected plant used in large stations. The figures show how much can be gained where the fluctuations in output can be lessened, so that the dynamos need not be driven by engines excessively large for the average amount of work to be done.

The current taken in starting the car is from 40 to 50 amperes with the series parallel controller. This current corresponds to 1,600 to 2,000 lbs. horizontal effort at the periphery of a 33-inch wheel, and accelerates the car under ordinary conditions about 2 feet per second.

The energy taken per car mile remains fairly constant through a wide range of speed, which points to the economy of as high tramway speeds as safety permits. The practice in the United States of running the cars at from 4 to 6 miles per hour in the crowded streets, and 12 to 15 miles per hour in the outskirts, seems to the speaker to be reasonable, since accidents generally occur in the slow-speed districts.

The curves in Figs. 1 and 2, Plate D, show the speed, torque, and efficiency (including loss in gearing) of a good modern American tramway motor, designed for series parallel control. If this motor were adjusted to English practice the torque would be increased 50 per cent., and the starting current for the same conditions diminished to two-thirds of that quoted above for American practice.

Regarding the application of alternating currents to tramways, I may say the properties of the induction motor are not such that it may compare favourably with continuous-current motors for ordinary tramway work. Mr. Parshall.

I submit herewith for your consideration, in Fig. 3, Plate E, a torque curve of a well-designed three-phase induction motor which should be compared, as to form, with the torque curves of the continuous-current motors given above. The indirect application of alternating currents to drive commutating dynamos for the operation of tramways is being successfully carried out, and has the advantages of avoiding long earth returns and heavy feeders.

Regarding the experience in the United States with direct-connected railway dynamos, I may say briefly the results have been most gratifying. No mechanical troubles have been experienced either with dynamos or engines, and the safety and economy gained are even more marked than on direct-connected lighting dynamos. As an example of the service such plant has been put to, I may quote the Intramural Road at the Chicago Exposition. There were 14 trains of 67 tons each; scheduled time, including stops, 10 miles per hour; each train taking on an average 42 kilowatts, but frequently more than 250 kilowatts, so that the fluctuation of load on the 750-kilowatt 100-revolution engine and dynamo was regularly between 400 to 1,500 kilowatts. This, together with occasional short-circuits, threw on the plant great strains; still there was no trouble from any source, and after the apparatus was taken apart at the end of the Exposition it was found to be in perfect condition.

For those who are interested, I submit, in Figs. 4 and 5, Plate E, speed and current curves of one of the Intramural trains, which is a fair illustration of the fluctuation of current in such practice.

Captain SANKEY: Mr. Wilkinson in his supplementary paper says: "An over-load or short-circuit, when driving by belt, "puts a sudden brake on the periphery of the wheel, and a "shearing strain on the spokes." This is no doubt true; but it may be questioned whether the stresses so produced in the spokes can be of sufficient intensity, in a well-designed fly-wheel, to lead to accident, because the energy stored up in the rim of the Captain Sankey.

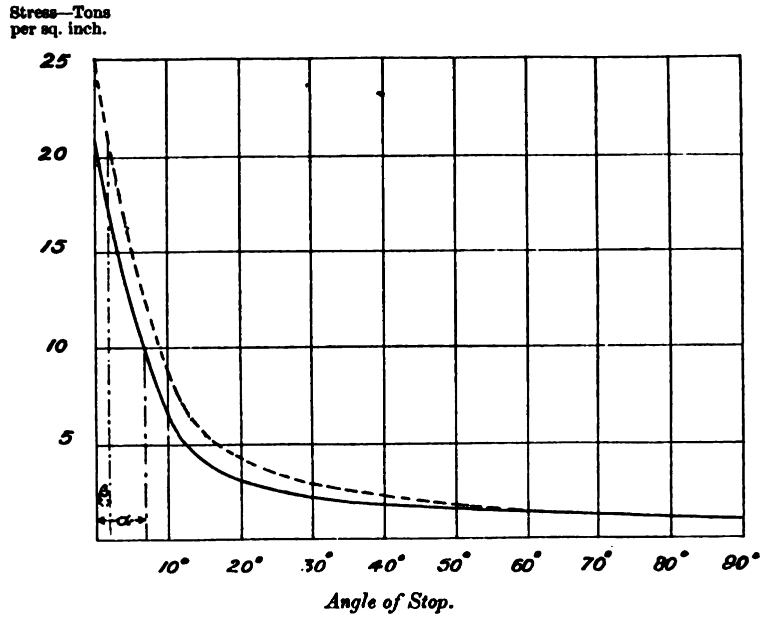
Captain Sankey.

fly-wheel is, so to speak, discharged directly into the belt—that is, it is taken up by the belt and does not affect the spokes. A different state of things occurs, however, in the fly-wheel of an engine connected rigidly to the dynamo it is driving. In that case the energy in the fly-wheel has to be discharged through the spokes, because the rim tends to get ahead of the boss, and so produces shearing and bending stresses at the boss, tending to break the spokes. That such stresses may be a serious question in the fly-wheels of slow-speed direct-driven sets is hardly open to doubt, and they may very possibly lead to accident; at the same time, there is no such risk with the small disc fly-wheels usual with high-speed direct-driven sets. The construction is enormously stronger, and the forces act with a leverage reduced in the inverse ratio of the speed.

It is often said that if a short-circuit takes place, the engine would suffer damage if rigidly connected to the dynamo. A moment's consideration will show that it is not the engine, but the armature of the dynamo, that is liable to injury, because the engine is protected, so to speak, by the fly-wheel. To put the matter beyond doubt, however, some calculations have been made, which are embodied in the subjoined figure.

The problem worked out is as follows:—A two-throw single-acting engine of 200 H.P., running 350 revolutions per minute, is stopped by a short-circuit. Find the maximum torsional stress produced in the crank-shaft by the inertia forces thus called into play? The point where the short-circuit should begin, in order to give the greatest stress, was found by trial, and is somewhat in front of half stroke. The protecting effect of the fly-wheel is omitted. The results of the calculations are shown in the Figure by the full line. The ordinates give the torsional stress in tons per square inch, and the base is the "angle of stop"—that is, the angle described by the crank-pin from the moment the short-circuit commences to the moment the engine is brought to rest. It is evident that the greater the angle of stop the less will be the stress. If the angle of stop is nothing, the engine is stopped *absolutely* instantaneously, in which case the energy of the moving parts of the engine is taken up in the spring action, or resilience, of

the crank-shaft. The stress is then considerable, namely, somewhat over 20 tons per square inch, as shown in the figure. The stress, however, drops very rapidly: at 10° it is about 7 tons, at 30° it Captain Sankey.



Torsional stresses in crank-shaft due to inertia of reciprocating parts, when engine is pulled up by short-circuit.

Full curve, single-acting engine	350 revs.
Dotted curve, double acting engine...	100 „

α and β, angles of stop for $\frac{1}{150}$th second.

is about 2 tons, and at 90° it has further dropped to 1 ton, which is not much in excess of the normal stress produced by inertia in the crank-shaft in the normal running of the engine. The ordinary stresses in the crank-shaft of the engine under consideration, due to steam pressure and inertia, do not exceed 1½ tons, it being necessary to allow a very wide margin for various reasons —such as, for instance, the effect of an excess of water in the cylinders, the shocks from which, though insufficient to burst the cylinder covers or break the pistons, may impose heavy stresses upon the crank-shaft. If we allow that the "short-circuit" inertia stresses may be as much as 10 tons per square inch, it still leaves a very ample margin, because the elastic limit for the quality of steel

Captain Sankey

used for crank-shafts is over 16 tons per square inch. On referring to the figure, it will be seen that stoppage within an angle of 7° produces a stress of 10 tons per square inch. At full speed the crank pin of this engine would describe this angle in 1-300th of a second, so that the stop would take place, roughly, in 1-150th of a second; and it is hardly conceivable that a short-circuit of sufficient intensity to cause so rapid a stoppage is possible. The problem has also been worked out for a double-acting two-throw engine of the same power as the single-acting engine, but running at only 100 revolutions instead of 350. The cranks were supposed to be set at right angles, as this is the more usual arrangement, and it is favourable to the double-acting engine, because when one set of moving parts has the maximum amount of energy stored in them—that is, when moving with the greatest velocity – the other set is very nearly at rest, and has no stored-up energy. In the single-acting engine, the cranks being set at 180°, both sets of moving parts not only attain their maximum velocity simultaneously, but this happens at the time of maximum leverage, or, at least, very nearly so, the difference being due to the angle of the connecting rod. The crank-shaft of the double-acting engine has been taken as of proportionate strength to that of the single-acting engine, and the stroke such as to give the same maximum piston speed, so as to make all the conditions the same, except the size, the revolutions, and the arrangement of the cranks. The result of the calculation is given by the dotted line in the figure, which is not very different to the full line for the single-acting high-speed engine; but it will be observed that, if this engine is stopped in 1-150th of a second, the angle described by the crank-pin will be only 2° instead of 7°, as in the case of the high-speed engine, and the stress in the shaft will be over 20 tons. The single-acting high-speed engine is therefore in a much better position as regards short-circuit than the slow-speed double-acting engine, notwithstanding the unfavourable arrangement of the cranks. Nevertheless, there can be no doubt that either of these engines is perfectly safe against any short-circuit that can possibly occur in practice, more especially if we take into account, as we have every

right to do, the protecting effect of the fly-wheel. Therefore, as previously stated, it is only the armature in a rigidly coupled direct-driven set which is liable to give trouble should a short-circuit take place; and it is also evident that the shaft and the armature winding can be made strong enough. Such a direct-driven set will be perfectly safe against any short-circuit; and that this is so in practice is confirmed by what Mr. Parshall has just told us happened at the Chicago Exhibition. Captain Sankey.

Mr. HOLROYD SMITH: I am strongly tempted to make some remarks relative to the paper of Dr. Preller on "Steep Grades," but that might lead me into occupying more time than one speaker is entitled to. I will, therefore, for the sake of brevity, condense my remarks. Mr. Wilkinson has given us a comprehensive survey of the progress of electric traction in America, and some idea of its present gigantic magnitude and importance. He has traced out very fully the growth and development, and given it to us in a manner satisfactory to those previously acquainted with the facts, and that must be very interesting and instructive to those who are now beginning to give attention to the subject. To the American financiers we owe our thanks, for they have demonstrated to the world that which we were only able to scheme and dream of, because the British purse-strings have been drawn too tight. The history given shows there is a danger in hastening too rapidly. The Americans have "caught on" the ideas very quickly, but in many cases have rushed into enterprise without availing themselves as fully as they might have done of the conclusions resulting from experiments and study in this country. The conclusions arrived at in Mr. Wilkinson's paper have long ago been enunciated and advocated here. I will, for the sake of brevity, not repeat the whole of them, but will come to the final one—viz., that the proper way is to put underground conduits in busy thoroughfares in large towns, and overhead conductors in suburban districts and in country places. It is gratifying to those in this country who have long advocated these views to find that the practical experience of the Americans has led them to the same conclusions. There is one opinion expressed in Mr. Wilkinson's paper with which, it might be expected, I Mr. Smith.

Mr. Smith. should entirely concur – viz., that in conduit systems it is better to have them placed in the centre of the track, not combined with the rails. On this I do not like to be as definite as the author of the paper. Had I been as certain, I should not, whilst constructing a centre-channel system, have worked out others for combined rail and channel. Referring to Fig. 12, illustrating a channel system laid in Chicago, it is to me a very interesting arrangement, for it is constantly reappearing under varying names; and, if I might take the liberty, I should call it free Love. I was also interested in the description given of the two-wire system, the American experience again demonstrating the truth of English predictions.

The other portions of Mr. Wilkinson's paper to which I desire to refer may be taken in conjunction with the consideration of Mr. Blackwell's papers. I wish specially to compliment Messrs. Blackwell and Dawson upon their paper. They set an example well worth following – viz., they do not content themselves, nor attempt to content us, with abstract figures. They show us how it is done. They bring a host of most carefully worked out details for our examination, illustrating how thoroughly the Americans have threshed this subject out. There is one feature of overhead wire lines—tramways peculiarly American—viz., what they call the trolley bar, but what I, following the name given to it by Mr. Beaumont, have always called the fishing rod. This is a decided improvement upon the shuttle as used by Messrs. Siemens, or the little rolling or sliding carriage used by myself, and adopted in the first overhead wire lines in America. There are certainly many points in favour of a slider on the wire, pulled by a flexible cord; but inasmuch as this involves a strain upon the wire, whilst the fishing rod bears under the wire, helping to support it, and can be pulled off one wire and changed on to another with ease and safety, and offers less risk to life than a slider, which may jump off (of course at the wrong time), these are sufficient reasons to counterbalance any points in favour of a slider and cord. I believe I am correct in saying that Mr. Sprague was the originator of this device, and the thanks of the electrical world are due to him. There have been

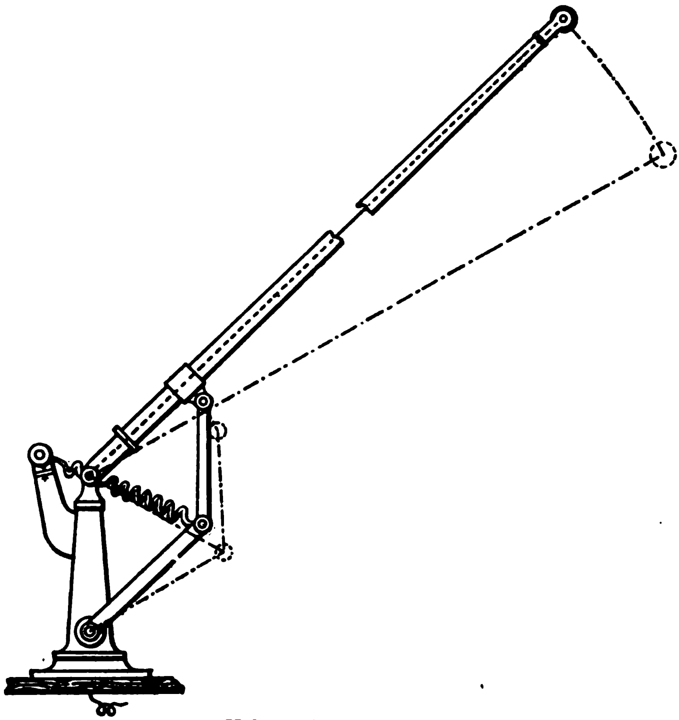
hosts of improvements of details appearing under other names Mr. Smith. and other patents, and all pushed with more or less energy; but one seldom hears of Mr. Sprague in this matter, and I here wish to publicly render him my thanks. There is plenty of scope for a separate paper on trolley bars, or fishing rods. Their forms are too numerous for me to enter upon a criticism now. It will be noticed that all exhibited and described are for use on cars with no roof seats. For cars with roof seats the arrangement of long horizontal springs at the back would be prohibitive. In overhead wires the rod is subject to a considerable deflection, especially when low bridges have to be passed under, and yet the pressure of the contact-making pulley under the wire must be approximately uniform. Hence, the pull of the springs in all the examples shown is combined with cams at the end of the "trolley bar."

I will, with your permission, sketch on the black-board the method I adopted at Bradford when demonstrating the fact that electric tram-cars could run, and run economically, up steep gradients.

At the ends of the car, on the extension of the roof beyond the railings that guard the seats, I place a pedestal somewhat like the upright of a jib crane, and free to swivel; near the top of this upright the base of the fishing rod is hinged; near the base of the pedestal is hinged a shorter bar, carrying at its end a link coupled to a joint on the fishing rod, thus forming a parallelogram. From the pedestal, at a point more or less close to the pivot of the fishing rod, is attached a spring (or nest of springs), the other end being attached at the pivot point of bar and link, the springs thus passing diagonally across the parallelogram. The tendency of the springs is to close the parallelogram and keep the fishing rod at its highest position. It follows that if the fishing rod is depressed the parallelogram is expanded and the springs stretched; the varying leverage obtained by the parallelogram compensating for the increased tension of the springs, thus securing a uniformity of pressure on the end of the fishing rod through a wide range of movement.

I have here the base of one of the fishing rods employed; also the collector pulley, through which has actually passed a current

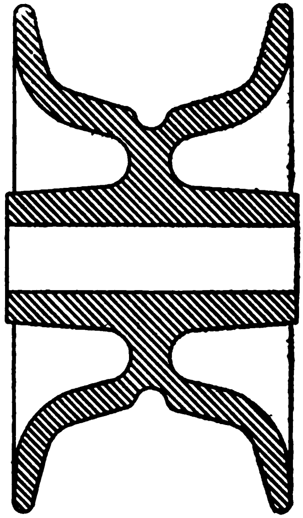
Mr. Smith. taking a fully loaded car weighing 10 tons up a gradient of 11¼ and round a curve at a speed of 10 miles an hour, and stopping and starting on the hill and curve whenever required.



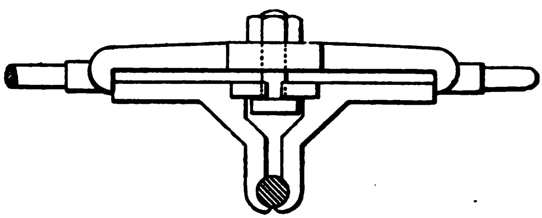
Holroyd Smith Trolley.

It will be noticed that my pulley differs somewhat from the type that prevails in America. When the trolley bar is attached to the centre of the car, and assuming the wire to be fairly central over the track, then when the car is travelling round a curve the lateral deflection is less than when attached to the rear of the car. I do not say that the American form would not work under the conditions that then existed, but I should be doubtful of the result. It will be seen from the sketch that the pulley used, whilst providing a suitable groove for the electric wire on the straight, allows considerable cross lay on the pulley without fouling the flanges or allowing the wire to escape. This enables contact to be maintained with less upward pressure than is necessary when the American shape of pulley is employed.

Messrs. Blackwell and Dawson show a number of devices for some unknown reason called "ears." They are the means of attaching the overhead electric wire to the span wire or cross arm, and insulating it therefrom. They are ingenious, well made, and no doubt effective, but, to my thinking, too heavy, too expensive, too troublesome to attach, and most of them incapable of being afterwards adjusted when once fixed. This simple device fulfils all the conditions they do, and at the same time is lighter and more easily fixed, and can be adjusted or removed at any time. The theory of it may be interesting, and is better explained by a sketch— Mr. Smith.



Holroyd Smith Trolley Wheel.

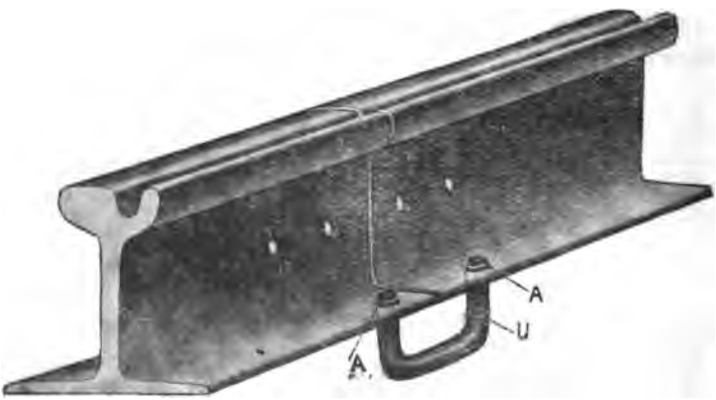


Holroyd Smith Overhead Wire Clip.

A split tube of india-rubber or other insulating material is first slipped on the span wire, and over this is placed a bridge, or saddle, having forked lugs at either end projecting downwards. Two angle plates of special form are placed below; one arm of each angle abuts against the forked lugs, the other arms are provided with hollow recesses for gripping the electric wire. Lugs, or projections, are formed at the corners of these angle plates, engaging with the heads of two bolts which pass upwards through the top cover plate or saddle. By tightening the nuts on these bolts the angle plates are drawn up, strutting against the forked projections at one end, and causing the hollows at the other end

Mr. Smith. to grip the electric wire. It will be seen that by slackening the nuts either or both wires can be slid through the clamp. The sample shown is one that has been in practical use, and through a misadventure has withstood abnormal strains much more severe than any likely to occur in regular practice.

The authors of both the papers have paid much attention to rail-bonds and feeder wire, and I have been most interested in listening to the historical development. One described, and to which I understood some preference to be given, is very similar to the one I devised and employed when constructing the Blackpool line more than 10 years ago. It simply consists in boring holes in the flanges of the rails near the joints, clearing them out with a taper reamer, then inserting the ends of a bent copper tube, U, which bridges from hole to hole, and driving into the tube-ends taper metal plugs, A A, forcing the copper into close mechanical

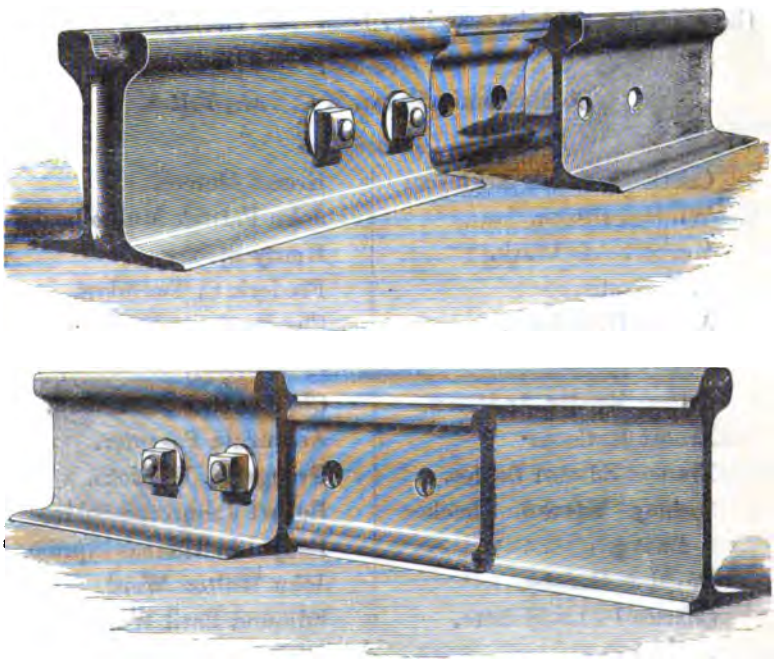


Holroyd Smith's Rail-Bond.

contact with the clean steel of the rail. During the repairs which have taken place in Blackpool this spring some of them were exposed, and I found them to be in excellent condition after 10 years' use. I may also say that the rails are, and were at the outset, connected with the negative terminal of the dynamo by insulated copper cable of ample dimensions.

An electric tramway involves more than the distribution and conversion of electric energy, and I am glad to hear so much

stress laid upon the necessity of a good permanent way. The liberty allowed in America has given the engineers there a much freer course than we have here. The absence of the groove, compulsory in this country, gives much freer running. It is well known that the chief difficulty with a tramway is the rail joints. Though the plan of welding is very attractive, I am at present sceptical as to the result. I have long advocated a double tread rail, and car wheels with centre flange; and I am glad to know the plan has been adopted in Buda-Pesth, which is decidedly the best example of electric tramways I am acquainted with. The double tread lends itself to easier running through points and crossings, and I wish to show you a construction of rail that practically gets over the joint difficulty, and lends itself very easily to efficient bonding. Mr. Smith.



Holroyd Smith's Double Head Rail.

You will see by this model (the accompanying figures are from a photo of the model) that the rail is in two halves of like section, easy to roll. They "break joint" midway in the length

Mr. Smith of rail section; and a centre fish-plate is employed, which also acts as a locking plate. Short plates of same section are placed at every tie-bar, thereby binding the whole firmly together.

The bonding is done by boring a hole right through the two webs, inserting a thin copper pipe, and driving taper plugs into each end, or a copper bolt with conical head and nut can be employed. These "bondings" can be put in at frequent or long intervals, as the demand upon the conductivity of the rail as a return may require. There are other advantages of this type of rail that will be apparent to those accustomed to tramway construction. I have avoided on the present occasion making any remarks upon the motors, gearing, and generating plant, and I thank you for having allowed me to occupy so much of your time.

The PRESIDENT announced that the scrutineers had reported the following candidates to have been duly elected:—

Member:

Sir Benjamin Baker, K.C.M.G., F.R.S.

Associates:

Charles Edwards Atkinson.
William Brown.
Herbert Ade Clark.
C. J. Evans.
Arthur H. Gibson.
Ernest Mercer.
John Patrick Mulholland.
Henry Stooke.
Frederic C. Twemlow.
Charles Selby Whitehead.

Students:

Arthur Verden Anderson.
Ernest R. Cook.
Francis Edward Davies.
Sydney Edward Thacker Ewing.
David J. Gadsby.
Charles D. Le Maistre.
Charles Henry Marshall.
Arthur du Pasquier.
George W. D. Ricks.
Robert Johnstone Scott.
Benjamin Thomas Squibb.
John Walton Ward.
Edmund Basil Wedmore.

The PRESIDENT: The next meeting will be our Annual General Meeting; and, if time permits, the discussion of these three papers will be continued.

The meeting then adjourned.

The Twenty-third Annual General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, December 13th, 1894—Mr. ALEXANDER SIEMENS, President, in the Chair.

The minutes of the Ordinary General Meeting held on November 22nd, 1894, were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

Donations to the Library were announced as having been received since the last meeting from Mr. R. W. Blackwell, Foreign Member, and Mr. Albion T. Snell, Member; to whom the thanks of the meeting were duly accorded.

Messrs. G. P. Simpson, M. Holroyd Smith, C. P. Sparks, and F. R. Connell were appointed scrutineers of the ballot.

The PRESIDENT: I will now call upon the Secretary to read the Annual Report of the Council.

The SECRETARY then read the Annual Report of the Council, as follows:—

REPORT OF THE COUNCIL TO THE ANNUAL GENERAL MEETING, 13TH DECEMBER, 1894.

ELECTIONS AND TRANSFERS.

The increase in the numbers of members since the last Annual General Meeting is very satisfactory.

Inclusive of the candidates to be balloted for this evening, 14 Foreign Members, 13 Members, 145 Associates, and 123 Students, making a total of 295, will have been added to the register during the year; and 29 candidates have already been approved for ballot at the first meeting next month.

24 Associates have been transferred to the class of Members, 80 Students to the class of Associates, and 1 Student to the class of Foreign Members.

Deaths and Resignations.

Our losses by death have fortunately been considerably below the average, amounting this year only to 9. We have lost 4 *Foreign Members*—Mr. Nagayama, of the Japanese Government Telegraph Department; Mr. Tomas Taylor, of Bilbao; Mr. G. B. Prescott, at one time electrician to the Western Union Company, and who was the author of several works on telegraphy and other branches of electrical engineering; and Dr. K. E. Zetzsche, formerly telegraph engineer to the German Postal Service, and for many years editor of the *Elektrotechnische Zeitschrift*;—1 *Member*—Colonel R. Y. Armstrong, R.E., to whom special reference was made by your President at the last meeting;—3 *Associates*—Messrs. R. H. Harrison, Burton Brown, and S. M. Hancocks;—and 1 *Student*—Mr. John Venner.

Five Foreign Members, 10 Members, 18 Associates, and 12 Students have resigned during the year.

Papers.

Besides the valuable Address of the President, the following papers have been read during the year:—

Date.	Title.	Author.
Jan. 25.	Notes of a Trip to the United States and to Chicago	W. H. Preece, Past-President.
Feb. 8.	Some Notes on the Electric Lighting of the City of London	General C. E. Webber, Past-President.
" 22.	On a Method of Testing the Magnetic Qualities of Iron	Gisbert Kapp, Member of Council.
Mar. 8.	On Parallel Working, with Special Reference to Long Lines	W. M. Mordey, Member of Council.
" 29.	A Universal Shunt Box for Galvanometers	Professor Ayrton, Past-President, and T. Mather, Associate.
" 29.	The Best Resistance for the Receiving Instrument on a Leaky Telegraph Line	Professor Ayrton and C. S. Whitehead, M.A.

DATE.	TITLE.	AUTHOR.
April 12.	—Transparent Conducting Screens for Electric and other Apparatus	Professor AYRTON and T. MATHER.
„ 26.	—Cost of Electric Energy	R. E. CROMPTON, Vice-President.
	Notes on Electric Tramways in the United States and Canada (published, but not read) ...	H. D. WILKINSON, Member.
Nov. 8.	—Do. do. (Supplementary Paper) ...	H. D. WILKINSON, Member.
„ 8.	—Electric Traction, with Special Reference to the Installation of Elevated Conductors	R.W. BLACKWELL, Foreign Member, and P. DAWSON, Associate.
„ 22.	—Electrical Steep-Grade Traction in Europe	Dr. C. H. DU RICHE PRELLER, Member.

ANNUAL PREMIUMS.

The Council have awarded the Salomons Scholarship (value £50) for this year to Mr. Edward Ernest Hoadley, a student of the City and Guilds of London Technical College, Finsbury.

Only one of the papers read during the session 1893–94—viz., "Notes on Electric Tramways in the United States and Canada," by Mr. H. D. Wilkinson, Member—is eligible for a premium, all the others being by Members of Council; but the Council consider that paper fully deserving of recognition as containing a large amount of useful information collected at considerable trouble, and they have therefore awarded the Institution Premium, value £10, to Mr. Wilkinson.

The Students' Premium of £3 3s. for the session 1893–94 is awarded to Mr. G. C. Allingham for his paper on "Secondary "Batteries;" and the Council desire to make honourable mention of the two following papers, viz. :—"Notes on Alternate-"Current Transformers," by A. F. Berry, and "The Construction "of Resistances," by D. K. Morris.

The Council are glad of this opportunity of reporting that a great improvement has taken place in regard to the papers read at the Students' meetings.

Willans Memorial Premium.

The subscribers to a fund for commemorating the memory of the late Mr. P. W. Willans in connection with the branch of engineering in which he so greatly distinguished himself, have requested this Institution and the Institution of Mechanical Engineers to become joint trustees of the fund, the interest of which it is proposed to devote to the establishment of a premium to be called the "Willans Premium," and to be awarded alternately by the Councils of the two Institutions every third year.

Your Council have assented on behalf of this Institution to the request of the subscribers, and the Council of the Institution of Mechanical Engineers have done likewise. A committee has been appointed by each of the two Councils, and those committees are jointly considering and settling all necessary details, which will be in due course made known. In the meantime, it may be stated that the first award will be in December, 1897, and will be made by the Institution of Electrical Engineers.

Annual Conversazione.

The Conversazione was held at the Royal Institute of Painters in Water Colours on the 31st May, the attendance being again very large.

The Council last year considered it would be just, looking to the progressive increase in the expense of the President's Annual Conversazione, to enlarge the Institution's contribution towards the cost of that entertainment, and they this year came to the conclusion that for many reasons it was desirable that the whole of the expense should be borne by the Institution now that its funds can well afford the charge.

Annual Dinner.

The sixth Annual Dinner of the Institution, which took place on the 21st November, was held at the Freemasons' Tavern, and the attendance was considerably larger than last year. By the kindness of some of our members, means were afforded to the

manager of the Freemasons' Tavern for having the principal part of the dinner cooked by electricity.

Building Fund.

In accordance with the proposal put forth in the last Annual Report, and which appeared to give general satisfaction to the members then present, the Council have transferred the sum of £3,000 from the "General Investment Fund" to a "Building "Fund," and they have every reason to hope that they will find themselves able to increase that amount substantially each year.

Board of Trade.

The Council have again had the satisfaction of being invited by the Board of Trade to make suggestions in reference to important matters connected with the supply of electrical energy for the purposes of traction, and also in regard to light railways.

Financial Position.

The financial position of the Institution continues to be satisfactory, and there is every reason to expect that the accounts at the end of the year will show a considerable surplus.

During the year the further sum of £204 16s. 6d. has been invested on account of Life Compositions, and £1,010 3s. 6d. on account of the "General Investment Fund."

THE LIBRARY.

REPORT OF THE SECRETARY.

I beg to report that the accessions to the Library during the year number 56; of these, 2 were purchased, the remainder having been liberally presented either by the authors or the publishers.

The specifications of all electrical patents continue to be supplied to the Institution, by the kindness of H.M. Commissioners of Patents.

The number of patents applied for this year. up to November

28th, was 22.842. of which 1,203, or 5·26 per cent., were electrical.*

The corresponding numbers last year were 22,684 and 1,185, or 5·22 per cent.

The number of periodicals and printed proceedings of other Societies received regularly is, with some few exceptions, the same as last year. as may be seen by the list appended hereto.

The number of visitors to the Library to the end of November has been 712, of whom 120 were non-members.†

The corresponding numbers last year were 645 and 106 respectively.

F. H. WEBB,
Secretary.

APPENDIX TO SECRETARY'S REPORT.

TRANSACTIONS, PROCEEDINGS, &c., RECEIVED BY THE INSTITUTION.

ENGLISH.

Asiatic Society of Bengal, Journal and Proceedings.
Greenwich Magnetical and Meteorological Observations.
Institute of Patent Agents, Transactions.
Institution of Civil Engineers, Proceedings.
Institution of Mechanical Engineers, Proceedings.
Iron and Steel Institute, Proceedings.
King's College Calendar.
Liverpool Engineering Society, Proceedings.
Physical Society, Proceedings.
Royal Dublin Society. Transactions and Proceedings.
Royal Engineers' Institute. Proceedings.
Royal Institution, Proceedings.
Royal Meteorological Society, Proceedings.
Royal Society. Proceedings of,
‡Royal Society. Philosophical Transactions of,
Royal United Service Institution, Proceedings.
Society of Arts, Journal.
Society of Chemical Industry, Journal.
Society of Engineers, Proceedings.
University College Calendar.

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* Up to December 31st the number applied for was 25,272, of which 1,347, or 5·31 per cent., were electrical.—Sec.

† Up to December 31st the numbers were 773 and 128 respectively.

‡ Presented by Professor D. E. Hughes, F.R.S. (Past-President).

AMERICAN.

American Academy of Science and Arts, Proceedings.
American Institute of Electrical Engineers, Transactions.
Canadian Society of Civil Engineers, Transactions.
Franklin Institute. Journal of,
John Hopkins University Circulars.
Library Bulletin of Cornell University.
Ordnance Department of the United States, Notes.
Technology Quarterly.

FRENCH.

Bulletin de l'Association des Ingénieurs Électriciens sortis de l'Institut Électro-Technique Montefiore.
L'Académie des Sciences. Comptes Rendus Hebdomadaires des Séances de,
Société Belge d'Électriciens. Bulletin de la,
Société Française de Physique. Séances de la,
Société des Ingénieurs Civils, Mémoires.
Société Internationale des Électriciens. Bulletin de la,
Société Scientifique Industrielle de Marseille. Bulletin de la,

LIST OF PERIODICALS RECEIVED BY THE INSTITUTION.

ENGLISH.

Electrical Engineer.
Electrical Plant.
Electrician.
Electricity.
Engineer.
Engineering.
English Mechanic and World of Science.
Illustrated Official Journal. Patents.
Industries.
Invention.
Lightning.
Nature.
Philosophical Magazine.
Telegraphic Journal and Electrical Review

AMERICAN.

Electrical Engineer.
Electrical Review.
Electrical World.
Electricity.
Journal of the Telegraph.
Scientific American.
Street Railway Journal.

FRENCH.

Annales Télégraphiques.
L'Éclairage Électrique.

L'Électricien.
L'Industrie Électrique.
Journal de Physique.
Journal Télégraphique.

GERMAN.

Annalen der Physik und Chemie.
Beiblätter zu den Annalen der Physik und Chemie.
Electrotechnischer Anzeiger.
Electrotechnische Zeitschrift.
Verhandlungen des Vereins zur Beförderung des Gewerbfleisses.
Zeitschrift für Elektrotechnik.
Zeitschrift für Instrumentkunde.

The PRESIDENT: I have much pleasure in moving that the Report of the Council, and the Report of the Secretary with regard to the Library, as just read, be received and adopted, and that they be printed in the Proceedings of the Institution. I have but little to add, and I hope you will find that the Report is satisfactory, as it again shows a material progress in our Institution.

Mr. FERRANTI seconded the motion, which was unanimously carried.

Professor HUGHES: Gentlemen,—I have a very pleasing duty to perform this evening, viz., to propose a vote of thanks to the President, Council, and Members of the Institution of Civil Engineers. I think every one of us must feel deeply grateful to that Institution for all that they have done for us. Without them we should perhaps never have been in existence, and if we had been in existence it would have been as a very small Society indeed. It is due to their kind encouragement and aid that we have grown to be almost giants in size. They have not only encouraged us by lending us this hall, but they have instructed us and acquainted us with their mode of proceeding, so that we have been able to follow in their footsteps as far as practicable. We feel also grateful to them for their kindness in many other ways. I have great pleasure in moving—
"That the members of this Institution desire cordially to thank "the President, Council, and Members of the Institution of Civil "Engineers for their kindness and liberality in continuing to

"grant the use of their Lecture Hall for the meetings of this "Institution."

Mr. J. F. ALBRIGHT: I have very much pleasure in seconding the motion.

The PRESIDENT: In putting this motion to the meeting, I should like to say one word. You must all be aware that the loan of this hall at the present time, while the main building is being reconstructed, entails a great deal of trouble upon the servants of the Institution, for they have to come over on the occasion of each meeting from No. 9, where the Institution of Civil Engineers are temporarily located. There is no one living on these premises now, but, nevertheless, the Institution of Civil Engineers are extending their hospitality to us without any diminution whatever.

The motion was carried by acclamation.

Sir HENRY MANCE: We have had a very satisfactory report of a very prosperous year read to us this evening, and I think we ought not to forget the usual vote of thanks to the gentlemen who to a great extent have contributed towards it, namely, the Local Honorary Secretaries and Treasurers. I may say myself, as an old Indian member, that I am very well aware of the great amount of trouble which is taken by the foreign Secretaries in looking after the interests of this Institution and maintaining a friendly interest in our proceedings. It is not always easy to get foreign Secretaries, and therefore I have much pleasure in moving—"That the thanks of the Institution are due to the "Local Honorary Secretaries and Treasurers for their kind "services during the past year."

Mr. RICHARD AYLMER seconded the motion, which was carried unanimously.

Mr. CROMPTON: I have to move—"That the best thanks "of this Institution are due to your Honorary Treasurer, Sir "David Salomons." This Institution has grown to be a young giant, as has been very aptly said just now. The care of your funds has become a very important matter, especially as regards our investments, and the watching of their growth and encouraging them by every possible means. I need not remind you that

Sir David Salomons has spent infinite care and trouble on your behalf, and that he has many projects very near his heart for your benefit, one of them being the idea of this Building Fund, which I hope at some not distant date will put us in possession of a building of our own.

Mr. J. N. SHOOLBRED seconded the motion, which was unanimously carried.

Sir DAVID SALOMONS: Mr. President, Mr. Crompton, and gentlemen,—I thank you heartily for your kind vote of thanks. If I am anything, I am an enthusiast in all I take up; and although you have not always seen me upstairs in this room, I can faithfully say that there has scarcely been a Council meeting for the many years I have been serving your interests from which I have been absent. At the start of this Institution in 1871 I was not a member, but I joined very soon afterwards, when the members numbered very little over 600. On the 1st of January this year you had 2,316 names on your books. At this moment probably we number 2,500. But more than that, the size of the members' roll is less important than the fact that you have drawn into your ranks the greatest men of science and engineers of this land, as well as the leading men of foreign countries, which proves that this Institution is a power on the globe; and the circumstance is one we must congratulate ourselves upon, although it is ourselves that we congratulate. Your surplus, instead of being what I described some years ago, a surplus amounting to a sum of £200, which an accountant would show consisted of furniture, to-day consists of over £1,000 a year in solid cash—furniture out of the question. Since our prosperity increases from year to year, we have started a Building Fund, which I trust you will directly make into a permanent Building Fund, in order that the members of this Institution may show their generosity in giving considerable sums towards it. We should out of our surplus provide every year a sum which in 10 or 20 years would enable us to obtain a building as good as this one for our Institution, should such a course become necessary. This has always been my ambition, and I hope it will come true. It is said in England that foreigners — the

French and Germans in particular—are exceedingly thrifty and provident. We have started a Benevolent Fund, which has not been so largely patronised as it ought to have been; and I trust you will redeem the English character by showing that you will in times of prosperity help that fund, so that in times of depression members who are unfortunate will derive benefit from it. I trust that you will remember these words.

Mr. R. K. GRAY: Gentlemen,—I have much pleasure in proposing—"That the best thanks of the Institution be accorded "to the Honorary Auditors." We have heard what Mr. Crompton and Sir David Salomons have said as to the onerous duties of the Treasurer, and we must remember that the Honorary Auditors have also important duties to perform. I have great pleasure in moving—"That the best thanks of the Institution be presented "to the Honorary Auditors, Messrs. F. C. Danvers and Augustus "Stroh, for their services during the past year."

Mr. J. L. OVENS seconded the motion, which was agreed to.

Mr. MORDEY: Anyone who has received—as I did this morning—a solicitor's bill will understand how feelingly I can move the following resolution, viz.:—"That the best thanks of the "Institution are due to Messrs. Wilson, Bristows, & Carpmael for "their kind services as Honorary Solicitors during the past "year."

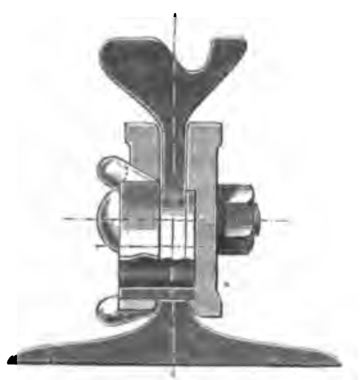
Mr. W. R. RAWLINGS seconded the motion, which was unanimously agreed to.

Mr. G. L. BRISTOW: Mr. President and gentlemen,—I feel exceedingly obliged to you, on behalf of myself and my partners, for the very kind resolution which you have passed. It has always been a pleasure to me to be associated and to have anything to do with this Institution, especially when I hear it is in so flourishing a condition. One always likes to be associated with success. It has really not been very much trouble to me; but if I have been able to render any service I have been exceedingly glad, and shall be equally glad to do so in the future. I recollect that when I first came to London—I think in the year 1850 or 1851—my late partner, Mr. Wilson, was then very actively engaged in supporting the Cooke and Wheatstone

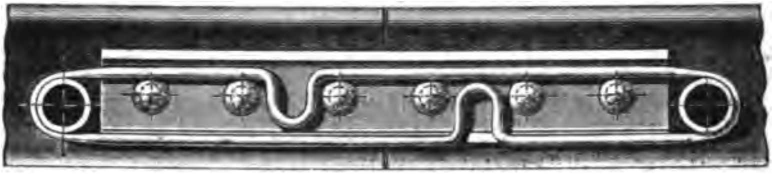
patents in Court. Those patents, I believe, shared the same fate as others in that respect—that they had to establish themselves before the Judicature of our land; and I think that ever since then I have been more or less closely associated with electrical matters, without, of course, knowing very much about their scientific features. I can assure you that it is always a great pleasure to me to act for you.

The adjourned discussion on the papers by Mr. H. D. Wilkinson, Messrs. Blackwell and Dawson, and Dr. Du Riche Preller was then resumed.

Mr. Robinson. Mr. FOLEY ROBINSON: The excellent papers we have heard read leave an impression that elevated conductor work has arrived at a high state of perfection, and but little room for improvement is left in regard to frogs, crossings, insulators, and trolleys. When, however, rail-bonding is touched upon, varied, and in most cases unsatisfactory, are the contrivances brought before us. I allude to the lack of due proportion between contact surface with rail and sectional area of conductor. This deficiency having already been dwelt upon at some length early in the discussion, I will draw your attention to a new form of bond, which I think you will allow possesses a certain amount of merit, and drawings of which I have placed upon the wall. You will see that the bond has tubular terminals, which are expanded in the ordinary way adopted by boiler-makers for expanding their tubes into position. Briefly, the conductor is made with large tubular terminals, which are expanded into holes in the rail webs. Mr. Yarrow, of torpedo boat fame, found by experiment that the tubes so treated, if they were free, would become slightly larger, and the holes, if free, would become slightly smaller—in short, that the surfaces in contact were forcibly pressing each other. I am



aware that taper plugs may be used to obtain a similar effect, but the cost of the large sizes would be prohibitory. Unless carefully made they would be most unsatisfactory, bearing and causing pressure only on a few points. In conclusion, no fear, I think, need be entertained that heavy girder rails would be Mr. Robinson.



materially weakened by large holes near the neutral axis. I have only ventured to make these few remarks because the rail-bond seems to have been in the past (what I hope it will not be in the future) rather an unhealthy vital organ in the overhead system.

Mr. F. B. LEA: I am glad of this opportunity to make a few comments on electrical rack railways in general, and also to offer one or two suggestions with regard to points arising on that subject as now brought forward, which may be thought worthy of consideration in Dr. Preller's reply. In the first place, I think he will confer an undoubted benefit upon us if he would give exact particulars with regard to the great saving which he claims for the use of electrical rack lines as compared with those operated by steam. Of course, as electrical engineers, we are all prepared, not only to admit, but also to advocate a very great economy in the use of electrical energy in any traction method; but at the outset it seems to be a little unwise to claim too much, or try to prove too favourable a case. As I understand it, the difficulty hitherto has been in finding two really similar lines which may be at all adequately compared as regards the two methods. In the second place, I should be glad if he can give the cost of motor repairs on the Barmen line, which is one of those he mentioned as being worked by electricity. One would be inclined to think offhand that this item must be rather a heavy one, owing to the fact that the Barmen road is built on the plain step-ladder rack principle. The incessant jolting and jarring to the motors and Mr. Lea.

Mr. Lea. gear would, I think, involve a great many loose connections, and also some amount of what the Americans call "throwing solder" at the commutator joints, especially when the motors get at all hot through excessive current or long use. I do not, of course, allude to the jolting due to the unevenness of the roadway, but that caused by the load partly coming on and going off as each tooth of the engine pinion engages and disengages with the line rack. There are other rack railways which seem to be of slightly better design, because not only the engine pinion teeth, but also those on the line rack, are staggered with respect to one another, and therefore they maintain continuous tooth contact throughout the whole of each revolution. With regard to the general subject, it will be evident to all those who have heard Dr. Preller's able and interesting paper that he has confined his attention entirely to what may be called isolated or independent lines—that is, to those lines which have no immediate or material connection with adjacent systems. They all seem to be designed and built for a purpose like that of the famous Duke of York, and without any ulterior motive—that is, simply for marching up a hill and marching down again. It must be remembered that the field for electrical rack railways covers far more ground than that occupied merely by these isolated lines. At the present moment there are on the Continent and elsewhere a large number of rack railways on main or continuous trunk lines traversing mountainous districts, and as regards some of these Dr. Preller himself has given some very good descriptions in the technical Press. These lines, so far, have been operated by steam locomotives of a combination type. Each engine has a double set of cylinders. One set actuates the ordinary adhesion wheel system in the usual way, and the other set is brought into use additionally on the rack system for working the engine pinions. Steep-grade systems of this type on a through route of railway or tramway, it is admitted, I think, effect a very great saving both in capital charges and working expenses, and their advantages in this direction become even more pronounced when electric traction takes the place of steam. It is quite feasible to construct electric locomotives of the combination type suitable for rack and

adhesion work, either or both, as the case may be, as is now done with steam engines. With regard to the Barmen line, I feel sure that its value would be much increased if it were materially connected at each end with the adjacent tramway systems, so that the same rolling stock might travel a considerable distance irrespective of the traction being obtained by means of a rack or by adhesion in the usual way. It is greatly to be hoped, and it can almost be expected, that the great extensions soon to be made in this country in the direction of light railways and tramways will afford numerous instances where lines of this character may find advantageous employment in some such way as I have sketched. Mr. Lea.

Mr. J. H. McGRAW: I thank you kindly for inviting me to speak, but I came to listen to the discussion rather than to say anything myself. I am sure, as has been said, that there is much to be learned by the study of what our neighbours are doing along the same line of work. For my part, I am indeed glad of the opportunity of spending a few weeks on this side of the water, and of learning something of what you are doing in the way of cable and electric traction. Rapid transit with us has come to stay. It is a feature of our daily life. We have made much progress during the past few years in both cable and electric traction, and, while we have made our mistakes, and have been compelled in some instances to rebuild faulty work, the results on the whole are highly satisfactory, and we may say most truthfully that we are very proud of our street railways. We feel very sure that England will soon be abreast of us in this development, and will no doubt make many improvements on present methods and practice, which will help to make the tramway interests of England as important an industry as it is with us in America. Mr. McGraw.

I have not had the pleasure of hearing the papers which are under consideration, and therefore do not feel competent to discuss them. I will take this opportunity, however, of inviting you all to come to the States and see for yourselves what we have done. We will give you a royal welcome, and every opportunity for investigation to the fullest extent. The next Convention of the American Street Railway Association will be held at Montreal

Mr. McGraw. in October, 1895, for the first time under the British flag. Perhaps you can make it convenient to come at that time, making a tour of the States, and ending up at the Montreal Convention.

General Webber. General WEBBER: We are all grateful to the last speaker for the very kind and cordial offer which he has made to the members of this Institution, and we hope there are some of us present who will be ready during the next year or two to respond to his invitation. From our experience of the past we feel sure that all he tells us, not only as to the welcome we shall receive, but the interesting information we shall acquire, will be fully borne out.

You, Sir, know that you were lately delegated by this Institution to attend a meeting at the Board of Trade on the subject of light railways, and I had the honour of being joined with you in that delegation. The meeting was so fully reported in the Press that nothing that may be said about it here by those who were present, as to what passed, can in any way be a breach of confidence. All of us who have read the papers during the previous three weeks, particularly the *Times*, must have felt that one of the objects of that meeting was to promote the extension of light railways, especially with a view of assisting agricultural industry in this country, which those who have to do with it know is in a very depressed state, and to enable that industry to compete with the great influx of produce, chiefly for domestic use, which is going on from the Continent. Those who are well acquainted with what is going on in Belgium, Denmark, France, and Germany, and also Spain, will know that these railways which have been built are very largely supported by carrying from the centres of production—that is to say, the small homesteads and homes of the producers—the very produce which finds its way to the markets in London. When you know that, I am sure you cannot help feeling that the consideration of those who are promoting light railways must be turned to enable our agriculturists to have the means of transport not merely from centres, but almost from the very fields and from the homesteads where the produce is grown or gathered. In considering this

subject, it has struck me that electrical engineers have a condition of things to think of which has not been so prominently brought before us as it might have been. If light railways of the gauge such as suggests itself to my mind as suitable, with portable branches which can be laid into the fields and homesteads as feeders to be worked by hand, can be constructed, it is quite evident, if they are to be used along roads and lines of communication in which they are to be of real assistance to agriculture, there will perhaps be not more than two trains each way per day. I do not know how the electrical engineer is going to provide a locomotive to draw those trains economically unless it is going to carry its own power. It seems to me that you cannot expect to include the cost of a generating station, with an overhead conductor, for a line costing, say, a total of £2,000 a mile, and that it would never pay to keep your generating station in use for the purpose of running three or four trains a day. I cannot help thinking that here we have a future for traction by storage; and it is a point which I believe will, if studied and carefully thought out, and the experience that we have already gained applied (I do not think it has been at all fully applied as yet), enable us to further this great object of being able to take trains for agricultural purposes through a sparsely populated country with rare traffic, and so to bring the trucks to and from the sidings whence will branch off the short feeding portable lines which must necessarily be installed, and necessarily be capable of use, if we are going to bring the produce of the country cheaply from the points of production to the market. This consideration has pressed itself upon me, and I have nothing to suggest more than that the very small experience we have had in this country need not leave us hopeless on this point, namely, that traction with storage is a thing which must now be looked to for further development, and that there is a really useful and profitable field in that direction if our engineers will only give it their attention. General Webber.

Professor SILVANUS THOMPSON: I do not propose to add anything to the technicalities of the discussion th[...] going on. I join my thanks to the authors of the [...] for the very valuable information that they have [...] Professor Thompson.

Professor Thompson. this Institution, but I rise to speak very much more in the strain of my friend General Webber. I am one of those who have had the advantage of seeing what has been done on the other side of the Atlantic. Going over last autumn, I remembered very well from my previous visit of nine years before what an unpleasant effect was produced on the mind of the average Britisher by the arrangements of overhead wires and cables that at that time disgraced some of the American cities. Knowing that I had to now see something further—the trolley work, the overhead wires, the works that had sprung up in connection with tram-cars—I expected that the feelings of disgust that I had experienced nine years before would recur with some intensity. However, I came home with very different ideas, because our American cousins have amended their ways a great deal in the matter of overhead wires; they do not have quite the same ramshackle arrangements of telephone wires as formerly, and their electric lighting wires are very much improved, and in many cases laid underground. As one who objects very much to all these networks of overhead wires, I am bound to say I came back with this strong impression —that of all the different kinds of overhead wires one may see either in America or in this country, the overhead construction which least disfigures the landscapes is that of the modern trolley line for tram-car traction. Having made that statement, I would like to say that I think not even our American cousins have entirely realised the importance of what they have done in constructing so many hundreds and thousands of miles of light rails carrying electric tram-cars from their centres of population and industry into the surrounding districts—I mean they have not realised the importance of this thing to themselves as a social factor. Any-one who visits, for example, Pittsburgh now, and who knew what Pittsburgh was 10 years ago, will see that already the rapid transit from the centre of a thickly populated town to the out-lying districts has had a distinct social effect. The workmen, instead of crowding into barracks and tenements in a densely populated street, will to a much larger extent than before live in little workmen's villas, each standing in its own separate plot of ground, two or three miles away from the centre, where life is

more healthy, and the children happier, and where true civilisation is much more possible. We are returning in some respects to the more primitive civilisation of the village, in lieu of the desperate decivilisation of the densely populated town. This is due very largely to the fact that cheap and rapid traction is possible by means of electricity. Several other facts struck me in the social bearing of rapid electric traction, namely, that a great part of the lines that are spread out from town to town and from village to village across the State of New Jersey have been built by money found, I am told, very largely from two sources—the insurance companies of New York and Philadelphia, and the Pennsylvania Railroad. These two facts are very striking. If there is one body that looks out for a sound sort of investment, I suppose it is an insurance company; and if there is one body whose investments are entitled to be regarded with respect, they are the investments of a railway company. Why should it pay any railway company like the Pennsylvania Railroad to promote tram-car transit by means of electricity? Simply because of this —and our own great railway companies in England will find it out—that it is a distinct gain to clear out the local traffic near the terminus stations and allow main through traffic a freer course. We shall find it an important factor here if we can have electric lines running out from our terminus stations a few miles into the country, feeding the traffic at the terminus stations, so that the local traffic that chokes the main lines will be proportionately lightened. Further than that, we shall have the public very much better satisfied with the service they get between their homes and the populous centres where they resort in the daytime. There are many railway lines, no doubt, in this country—small branch lines off the main lines—which at the present time are worked by large railway companies at a disadvantage. Small lines are often built as a speculation, and, not having paid, have been taken over in despair by a larger company. Those lines do not pay at the present time by steam traction, but they would pay by electric traction, because, as General Webber remarked, where it would not pay to run two or three long trains a day it would pay to send one car every hour, or every half-hour, by Professor Thompson.

Professor Thompson. electric means. Here again the social question comes in. We want our civilisation to be improved and aided by this new means of traffic, exactly in the same way as civilisation has been improved and aided by having steam traction against the more primitive methods of travelling. This raises, however, another question, namely, whether it is not advisable to keep in our electric lines to the well-recognised gauge used for our railways, and to the well-recognised style adopted in our rolling stock. It would be much better in all future schemes to consider the adoption of a common gauge for electric tramways, so that the rolling stock should be capable of running, not only on the tram rails, but also on the usual rails employed on the heavy railways of this country. That, of course, is a very large question, but I think it would be a great disaster if we did not consider it now in all its bearings. We do not want to have perpetuated in electric traction the same kind of miserable mistake which was made in steam railroads, when the battle of the broad and narrow gauges had to be fought out.

Mr Wain. Mr. W. J. Carruthers Wain: I thank you for your courtesy in inviting me to your meeting, and also for inviting me to speak—not that I am able to add anything to the marvellous store of knowledge which has already been imparted to the members by previous speakers, and by the authors of the papers, to whom I, in common with others, feel that I owe a deep debt of gratitude for the information that they have given to me. I have, however, possibly some little excuse for speaking for a few minutes, because, owing to circumstances possibly entirely beyond my control, I have probably had more experience of electric traction in this country than (I hope I say it with all due modesty) any other man. The reason is exceedingly simple: it arises in consequence of my position as President of the Tramways Institute of this country, and also in consequence of my personal association with a variety of companies on which electricity has been tried.

General Webber and other speakers have referred to storage batteries. My experience with them has not been the overwhelming success which we all hope for and desire. No doubt to some extent the blame for that rests upon a variety of shoulders.

Mine, I admit at once, are not broad enough to carry all the blame, Mr. Wain. nor do I desire that unenviable distinction. The failure of traction by storage batteries in England has been due to a variety of causes, and not necessarily to the batteries themselves. For example, when you ask an accumulator car to grind its way through snow and ice over a corporation-made line an inch and a quarter wide to gauge, what could you expect but an exceedingly rapid deterioration of those batteries? If, as has been done, batteries are allowed to wear out and are not replaced, and you charge them every journey, every six miles, what can you expect but that your working expenses will mount up in an alarming proportion? But for this I accept, as I had not, any responsibility. Therefore, by the ignorant and prejudiced, traction by storage batteries is absolutely condemned.

General WEBBER: Are you speaking of Birmingham?

Mr. W. J. CARRUTHERS WAIN: I am; but I do not appear here to-night as an advocate of any particular form of traction; my object as President of the Tramways Institute is to find out the best form of traction, and to that object I have devoted a very considerable amount of time. I have experimented with, I was going to say, air, fire, and water. I have used steam by means of locomotives travelling on common roads; I have tried compressed air; I have tried, and am trying, oil; I have tried, and am trying, gas; I have tried accumulators of all types—of the E.P.S., of the Epstein, and of the Julien and Jarman—on different roads; and I have tried—and I take credit for saying so, and I hope you will think I am entitled to that portion of credit which as a director of a company ought to fall to my share for introducing to England the first complete system, over an extended area, of traction by means of overhead wires—that system or that service which is in complete and successful service and successful operation to-day in the Black Country, of which you have heard in the papers, and of which you have also heard incidentally. In South Staffordshire there is a complete system equipped, I hope and believe on a method which approves itself to those gentlemen who have preceded me, and which, to my mind, is not only satisfactory from a

Mr. Waln. pecuniary point of view, but satisfactory even to those gentlemen who implored me, almost with tears, to do nothing in erecting these overhead wires which would deface the picturesque beauty of the Black Country! I have endeavoured to keep my word. I do not think that the scenic advantages of the Black Country have suffered at my hands; and I am in hopes, by means of information such as has been supplied to us by these papers, and by means of the diffusion of knowledge which your Institution is able to convey to the public, that we shall see a very large development of traction by means of overhead wires, because I can conceive of nothing more economical and more speedy and more pecuniarily advantageous to those who put their money into them. On that point I should like to say that I do not view it from the selfish point of view of one of the gentlemen who attended the Congress last week at the Board of Trade, who, as the representative of the steel and iron industry, prayed for a wide extension of light railways all over the kingdom, because he said that there never was a time when the iron and steel industry needed it more. I am not interested in iron and steel, and my shares in electrical companies amount to £4; but from the point of view of the traveller, and from the point of view of the tramway director who wishes to see absurd and obsolete restrictions removed, and to see railway and tramway legislation brought up to date in England as it has been brought up to date elsewhere, I do hope for the very best possible results from this Conference and Committee on Light Railways, of which your honourable President and myself are members. I am quite sure of this—that he will manage to make his "still small voice" heard at the right moment, and that the result will be satisfactory both to you and to me.

I really apologise for detaining you, because I do not think I have conveyed any absolute information to you, excepting for the fact that I have done what I can to promote electric traction in this country, and I shall only be too glad to see the opportunity to do more. At the present moment I am doing a little something with reference to accumulators. I am arranging for the demonstration of a battery of which you may have heard, and which has been brought under my notice, and the merits of which, at any rate, I

intend to try. I do not profess to know anything at all about it, because if I once called myself an electrical engineer I should launch myself upon a sea of doubt and difficulty, and I do not know what harbour I should get to eventually; but I am going to try the "International Electric Storage Battery," which has been tried, as I understand, in Belgium and France. A demonstration of this battery is to be arranged in Birmingham at an early date, and those who are interested in accumulator forms of traction will be glad to know the results of those trials; and, if you will permit me, I shall have the greatest pleasure in communicating those results to the Institution. Mr. Wain.

Mr. FERRANTI: The principal impression produced upon my mind by the various interesting papers which have been read to your Institution on traction is that, whatever other countries have done, we over here have done very little. It is an unfortunate state of affairs, and it may be interesting to consider for a moment what are some of the probable causes which have led to this backwardness on our part. In the first place, I think that we have a very exaggerated idea of the ugliness of an overhead system. This is a very unfortunate thing, because I am sure that the overhead system has been proved to be quite the cheapest way of working for the largest number of applications in the way of running tramways in and about our towns, and therefore it should receive the very greatest consideration. It is the one which I think is likely to be adopted first if other objections are put on one side. I have no doubt that still further improvements will be made which will render the lines better looking, and that, becoming accustomed to see them, we would forget that they were ugly, and think rather of the great convenience which they would give. The second great trouble appears to be that of obstruction to fire-escapes. I do not know how this is managed abroad. Perhaps in America the houses are too high to make it worth while trying to save peopl fire-escapes such as we know them here; but, however the be, most of the people with whom I have spoken have with this difficulty—that the wires were in the road of t escapes, and that therefore an overhead s Mr. Ferranti.

Mr. Ferranti

tolerated. I think the time may come when, if this is a fact, it will pay the promoters of a trolley-wire tram line to provide a modified form of fire-escape which can be worked without interfering with the wires, and present it to the authorities in the district concerned. There is, next, the question of danger, and I think this is far more imaginary than real. I have no doubt that accidents may occur by overhead wires dropping, but I think it will be of very rare occurrence, and I do not think it is a difficulty which should be set against the immense advantages that would come from rapid traction in our towns. There is another thing which has militated very much against the development of electric tramways, namely, the obstructions which have been put in their way. We have a custom here of always protecting the man who is in possession; that is to say, if there is an existing industry—we will say, for example in this particular case, the telephone industry—the whole legislation tends to protect that industry, without calling upon it to protect itself by taking a share in the proper re-arrangement of its methods. On the contrary, electric traction, which is the new industry, has to fight its way into existence without interfering with an existing system which almost seems as though it had been laid down with the object of courting every disturbing influence. I am afraid that this is one of the troubles which we will suffer from a good deal. Then I think there is another one. I fancy that, notwithstanding these various difficulties which I have pointed out to you, but which, of course, you are quite well acquainted with already, there is a far greater trouble. You know that everything of a new nature requires an immense amount of personal effort and continual work to bring it forward. Electric traction requires all the energy of the whole of the electrical industry, whether they are directly interested in this particular branch of the subject or not. Now, in the case of electric traction, this personal energy so much required is absent, as there is no one sufficiently interested in the development of any particular system the success of which, if attained, will reward their labours. The matter is too much public property, and therefore no one's business. I therefore think that one of

the great inducements—namely, personal gain—is absent in this particular case. I think that very likely this may have a good deal to do with there not being the great effort brought to bear in this country which I think would be necessary to introduce such a thing as electric traction as largely as it should be introduced. It may be possible a little later on to form some sort of association for this particular purpose, or for some committee, possibly of this Institution, to be formed which should receive reports primarily from all directly interested parties. There might then come the turn of those who are not directly interested. I would remind everyone here who is interested in manufacturing—and I think the majority of us are in some way connected with that branch—that, although they may do nothing in the way of electric traction themselves, they cannot do better than help those who are interested in it, because it will tend to an improvement in their own work by the filling up of shops of those who do electric traction with work of this kind, and so improve prices generally. I am afraid that these are considerations almost outside a scientific society; but still I think they have a right here, because anything which increases the general spread of electricity must certainly greatly increase the amount of knowledge on the subject, and also call for further scientific work to be done. Mr. Ferranti.

Mr. A. SHARP: There is one point in Dr. Preller's paper on which I should like to make a few remarks. Referring to variations of load at the generating station, and especially in starting trains, he says: "The most effectual remedy is the addition of an "accumulator battery, which absorbs any excess of supply from "the generator over demand from the line, and, *vice versâ*, makes "up for any deficiency of supply, so that the steam engine and "generator can always run at full and constant load." I should like to call attention to the merits of an ordinary fly-wheel as an accumulator of energy for the particular case of electric traction. The energy stored up in a moving body is proportional to the weight of the body and to the square of its velocity, so that if we can increase the velocity of the rim of the fly-wheel we get a considerable increase in energy stored. I hope to point out that we Mr. Sharp.

Mr. Sharp. have not yet reached the safe limit of speed for fly-wheel rims. Suppose we could run a fly-wheel at a rim velocity of 300 feet per second. One ton weight of rim in that case would store 95 H.P.-minutes; and with a fluctuation of velocity of only 5 per cent. above and below the average the available energy would be 19 H.P.-minutes; that is, a fly-wheel of 10 tons weight running at that speed, and with 5 per cent. variation of velocity, would give 190 H.P.-minutes available to meet the excess and deficiency of energy. At present, with the ordinary construction of fly-wheel, the safe speed seems to be about 100 feet per second. Our American cousins run things much closer than we do in this country in running fly-wheels at high speeds, and they unfortunately seem to get a good many fly-wheel accidents. The breaking of fly-wheels is usually attributed to the severe centrifugal excess on the rim.

Consider the rim of a fly-wheel as a circular ring rotating freely about its centre: the centrifugal forces acting radially outwards at all points produce a circumferential stress on the rim. At the speed I have mentioned—100 feet per second—the circumferential tension is less than half a ton per square inch; so that if we could use a free revolving ring as a fly-wheel, the safe speed could be considerably increased. But in any large fly-wheel with a small number of arms we have quite a different state of things. In a fly-wheel with, say, eight arms, there is at each arm an intense radial force directed inwards; so that each segment of the rim is in the condition of a beam loaded uniformly and supported at the ends. The maximum bending moment on any beam with load W per foot run is proportional to $W\,l^2$, l being the span between the arms. The bending moment can be reduced by reducing the span of the beam, so that if the number of arms is quadrupled the maximum bending moment on the rim is reduced to 1-16th. The solid disc fly-wheel, to which Captain Sankey has referred, is in this respect very much better than a fly-wheel made with six or eight arms.

A fly-wheel built on the lines indicated in my communication on Mr. Crompton's paper* will run safely at a much higher speed than even a solid disc fly-wheel, since the initial tension on the

* Journal of the Institution, Vol. xxiii., p. 542.

spokes produces an initial compression on the rim which is not neutralised until a high velocity is attained. For example, in a fly-wheel the rim of which weighs 10 tons and the spokes 2·2 tons (provided the proper initial tension be put on the spokes), the stress on the rim will be zero at a speed of 150 feet per second, and the tension on the spokes $5\frac{1}{2}$ tons per square inch. Mr. Sharp.

One of my fly-wheels has been put on the crank-shaft of a gas engine of 33 brake horse-power, by Messrs. J. E. H. Andrews & Co., Reddish, at the Central Schools, Sheffield. My fly-wheel replaces, and weighs the same as, one of the two ordinary fly-wheels usually supplied. Its diameter is 10 feet, that of the fly-wheel it replaces 5 feet 9 inches; so that, weight for weight, it stores more than three times the energy of the ordinary fly-wheel on the same shaft. Professor W. H. Watkinson is the consulting engineer. The engineer in charge of the installation writes: "The engine and dynamos were started on Monday, and ran with "full load for three hours. There is no perceptible variation in "the steadiness of the light, the finger of voltmeter remaining "constant throughout. On switching off the full load instan-"taneously, leaving a few lights on, there is no visible pulsation "in light, the voltmeter going up two volts, but remaining steady "throughout. There is a marked difference as compared with "the old fly-wheel when on, and running with varying loads. "The present 10-foot fly-wheel appears to meet all the necessary "requirements demanded for steady driving, either under full or "partial loads."

This high-speed fly-wheel is much cheaper, reckoned per unit of energy stored, than the old fly-wheel cast in one piece; and for electric traction, infinitely cheaper than batteries, there being no expense for upkeep and renewal.

Mr. J. D. Dallas: It is not perhaps generally known that one of the principal reasons for the great advance of electrical traction in America is on account of the gearing which has been adopted. In Richmond (Va.), on the first large electric tram-road, Sprague placed single-reduction gears on his motor. At first these did not give satisfaction, but on the gearing being altered to double-reduction the road Mr. Dallas.

Mr. Dallas. became a great success. The fault did not really lie with the gear, but with the motor, which was not strong enough to do the work. Double-reduction motors then became the vogue until 1891, when I think that nearly every road in America began to adopt single-reduction gears. By the introduction of single-reduction spur-gear motors the gear losses, which had amounted to 15 per cent., were immediately reduced to 6 per cent. for all working loads. Many different forms of pinions have been used. Bronze pinions are about as good as can be possibly used for reducing the loss and noise. Raw-hide gears at one time were thought to be excellent things, but were used for a short period only, as they rapidly fell to pieces. The next improvement was to laminate the raw-hide pinion by successive layers of raw hide and sheet iron or steel. But these, as soon as the edge was slightly worn down, cut the gear like so many saws, and were rejected. At present, preference lies between forged steel or bronze, in each case with the teeth cut out in a milling machine from the solid. I was in the testing department of a manufacturing company for a long time, and I think that they have come to the conclusion that there are smaller losses from a cast-iron gear than in any other form, the cast iron being close-grained, and with a considerable quantity of wrought-iron scrap mixed with it. This gives a very strong gear which works very well. I can give an illustration of the strength of these gears. I once saw a nut dropped by mistake into the gear, which was running about 900 revolutions armature speed. The nut was dropped in between the cast-iron teeth and a pinion. No mark could be discerned on the cast iron, but the nut was very plainly stamped on the steel, and the armature box was broken. Gearless motors are scarcely ever of any use for street traction purposes; it is almost impossible to make a light motor which will have a satisfactory efficiency. I have heard very little mention of carbon brushes. I saw them used on one of the first roads ever worked in Boston, and where the commutators used before the introduction of carbon were rapidly torn to pieces. These carbon brushes transformed electric traction from a dull failure to a signal success.

Mr Child. Mr. ARTHUR E. CHILDS [*communicated*]: On page 571 of the

Journal of the Institution of Electrical Engineers, issued July, 1894, Mr. Wilkinson refers to some tests made by Mr. James D. Rostron, of the Union Railway Company, Chester, Pennsylvania, bearing upon the conductivity of the earth as a return. Mr. Childs.

Mr. Arthur H. Allen, of the Westinghouse Electric and Manufacturing Co, who is familiar with the experiments performed by Mr. Rostron, states that, although apparently these experiments were conducted properly, and true results seemed to be obtained, yet, taking all the considerations of the locality into account, the results will be considerably modified. The method Mr. Rostron used to obtain the current through the earth plates was to place an ammeter in series with one of them and measure its current as a car was passing over it—which gave him $\frac{3}{4}$ ampere; while at the same time he states that he only obtained 0·51 ampere at the earth plate at the power house. Here is a discrepancy which requires explanation.

Earth plates on this road are distributed every 500 feet along the line, and some portion of the current passes through all of these, as well as from the rails into the earth between the earth plates. A large percentage of this current probably passes into the city water mains from the earth plates. Measurement, in fact, showed 12·8 amperes from this source of return.

It will therefore be seen that Mr. Rostron's assertion that the earth plates are of little or no value, and that the earth cannot be used as a return with any degree of success, are statements which must be accepted with considerable precaution.

There is no doubt that in many instances the earth return is used with success, as in the town of Williamsport, Pennsylvania, where the rails are not connected with the power house in any way whatever, the power house being situated about 1,200 feet from the line of rails at the nearest point. The system employed at Williamsport is known as the Siebold system, which consists in driving in every 30 feet, in between the rails, an iron pipe $1\frac{1}{2}$ inches in diameter, a distance of 12 to 15 feet. The pipe is then cross-connected with iron wire to the rails on both sides, and only a light bonding of the rails themselves is employed. This system has been satisfactory in this case—showing that the earth may be

Mr. Childs. used with success, as well as an all-metallic return. Another example of this case is at Middletown, Pennsylvania, where the power house is some two miles from the nearest point of the line of rails, and there is no metallic connection between the power house and the line whatever.

From the above it must not be inferred that the earth return can be employed successfully in all cases; but, on the other hand, it must not be indiscriminately condemned, as in many localities the condition of the earth—its moisture, composition, &c.—enables it to be used with great satisfaction. On the other hand, there are many instances where it is absolutely necessary to have a well-bonded line, with supplementary wires and good metallic connection with the power house. Such cases exist in large cities built on clay formation or on rock basis, where the resistance of the earth is too great to allow of the return of much current.

During Mr. Wilkinson's visit to Philadelphia he found that only one overhead trolley line was in operation, but since his visit this condition has been very materially altered. The total mileage of the street car systems in Philadelphia measures over 300 miles, of which about one-half has already been "electrified." All the principal streets now have trolley cars passing through them, and the increase of the earnings of those companies who have changed their horse power to electric power has been a surprise and pleasure to the stockholders of the various street car companies. The Philadelphia Traction Company, which now owns and operates the Market Street Cable road, is seriously contemplating the replacing of the cable by a trolley line, as their cable system has not been satisfactory in its working, and the breakdowns and stoppages have seriously interfered with its revenue.

In Philadelphia, with the exception of one or two lines, all the street car companies have applied for the right to change their horse power to electric power, and have obtained the necessary license, so that in the near future horse cars will be a rare sight in the Quaker City.

Mr. Dickinson. Mr. ALFRED DICKINSON [*communicated*]: I have read in the technical Press this week "Notes on Electric Tramways in the

"United States and Canada," read before your Institution on the 8th inst. by Mr. H. D. Wilkinson. Mr. Dickinson.

Although I am not a member of your Institution, as one having had some experience in the matter under discussion I am sure the members will not consider it an intrusion on my part if I ask Mr. Wilkinson a few questions. Does he mean that the £2,300 per mile of double track includes, in addition to the overhead work, the construction of the running rails and the necessary permanent way, and the sum of £4,000 per single mile for the conduit system to include this also? because, if he does, his estimates are totally inadequate. The cost of constructing a 4 ft. 8½ in. gauge tramway to comply with the specification of the large local authorities in this country would cost at least £5,000 per single mile of track, and the cost of the permanent way, including the conduit, would cost quite £10,000 per single mile of track. Mr. Wilkinson very kindly mentions my system as erected upon the South Staffordshire lines, and suggests that the difficulty of carrying outside passengers by the American system could be overcome by placing an awning over the cars. The fact that the wires are not over the cars in my system is but a small advantage. If the wire was carried over the centre of the track, and outside passengers could ride on top owing to the awning being over the car, that would not remove the great difficulty as to the passage of fire-escapes along the streets, neither would it remove the necessity with the American system of the innumerable number of guy wires which would be necessary to make the trolley wire follow the curvature of the track. I am sure the members of your Institution will not lose sight of the fact that American roads and streets generally are laid in a very different manner to the roads and streets in Europe. In America they are simply straight lines; but in Europe, speaking generally, and this country in particular, they are most tortuous and ever twisting, and the adoption of the American system here is therefore much more difficult than in that country. The great advantage of the South Staffordshire system is that the trolley wire does not need to follow the curvature of the track at all; it may be placed anywhere within a range of 26 feet—either 13 feet on one side or

Mr. Dickinson. the other. But this is by no means the limit, as we have experimented with a trolley pole over 20 feet in length, which would give a range of 40 feet. I see that one of the technical papers this week comments adversely upon the observations of Mr. Wilkinson where he speaks of the number of short-circuits upon one of the American systems, and they argue that the construction of overhead electric tramways leaves much to be desired. I therefore think it only right to state that on the South Staffordshire line there has been run in nearly two years about 600,000 car miles, and I am quite safe in saying that during the whole of that period we have not had the number of short-circuits Mr. Wilkinson states they have had in one day on a system in America.

Mr. Lundberg. Mr. G. C. LUNDBERG [*communicated*] : I can fully appreciate Mr. Wilkinson's remarks respecting the overcrowding of American street cars. Mr. R. W. Blackwell will corroborate me when I say that in Allegheny City, Pa., U.S.A., our record in 1888 was as many as 86 passengers up a 12 per cent. grade, in a car of a seating capacity of 22 or 24, the excess number finding room wherever possible. On many occasions this number was nearly equalled, and was accomplished in all weathers by track adhesion only, the electric equipment of the cars being two motors of 15 H.P. each.

The effectual bonding of rails is one of great importance, and I can supplement Mr. Wilkinson's remarks as to the disagreeable shocks experienced by pedestrians from contact with what were technically termed "dead rails" (?) in the West End Street Railway Company's system in Boston and Cambridge (Mass.) in 1889 and 1890, owing to inefficient bonding by the "soldered "rivet" method.

Perhaps the earliest examples of bonding on American street-railway systems were at South Bend, Ind. (Van Depoele), and Baltimore, Md. (Daft), both constructed in 1885.

The following is an extract from a description of the former line :—

"In order to make the track a *perfect conductor*" (the italics are mine), "strips of brass are laid under the joints of "the rails."

Judging from Mr. Wilkinson's paper, apparently this method did not come up to expectation. Mr. Lundberg.

The pioneer experiments of electric traction for street railway purposes on a large scale, as carried out by the West End Street Railway Company, of Boston, Mass., are beyond all praise; and it will not be out of place at this juncture to give all due credit to their enterprising president, Mr. H. M. Whitney, for his efforts in the practical solution of the problem.

In criticising the first applications of electricity for welding rails, it should be borne in mind that the extremes of temperature experienced in the States give the method a thorough test.

As regards overhead double-trolley systems, I think one of the earliest in the States was that adopted by the Bentley-Knight Co. in Allegheny, Pa.

Two sets of trailing collectors were employed, one set to each of the conductors, the latter being vertically one above the other, fixed to wooden posts on one side of the track. The current was conveyed by a twin flexible cable, terminating in a T-shaped socket, to spring contacts at the end of the roof of the car; the spring contacts being so designed as to allow the flexible cable to be jerked out should the collectors above meet with any obstacle to their progress along the conductors.

The line insulation, though of wood throughout, gave practically no trouble, and we were spared any anxiety from the use of span or guard wires, or bonded rail returns, having no need for them; we had plenty to do in keeping the motors in order, however, they being practically unprotected.

The method of shunting a series of lamps on each pole proved an excellent one for spotting earths, and I think to Mr. Charles H. Macloskie the credit of this method is due, as far as its adoption for electric traction in the States is concerned. The overhead section of the Allegheny line was single track, and in consequence of the difficulty of constructing overhead switches at the turn-outs, the car conductors exchanged trolleys when passing each other.

The "Love" conduit, so ably described, appears to me to be antedated in many of its details, and one cannot help but

Mr. Lundberg. recognise the Holroyd Smith and Bentley-Knight systems in its construction. As regards the depth of electric railway conduits, I believe, if the Blackpool (Eng.), Allegheny, and Boston (U.S.A.) conduits had been deeper, less trouble would have occurred, and the overhead system would not have been in such general use at the present day. As regards pockets, or hand holes, over each conductor support, these were present in the Boston conduit of 1888, and certainly proved advantageous. I notice in the "Love" system, contrary to the Bentley-Knight, there is no method of throwing the collectors completely out of the slot should any obstruction be met; I presume, if such should occur, the disabled car is pushed home as a "special" (as far as pedestrians are concerned). If fitted with the "throw-out" gear, the car could be pushed past the obstruction and the collectors re-inserted. The electrical brake was effectually used in Allegheny (a line which Mr. R. W. Blackwell may be justly called the parent of), two series motors forming the electrical equipment of each car. I personally know it was the means of preventing what might otherwise have been disastrous accidents on the steep grades there. It would be interesting to know the arrangement of the motors on the Zurich, Genoa, and Florence lines referred to by Mr. Preller in his paper as employing the electrical brake.

In Messrs. Blackwell and Dawson's collection, I can appreciate the improvements made in these necessary devices, which undoubtedly are the outcome of dearly bought experience.

Mr. Holroyd Smith, in his criticism, may say they appear clumsy and unsuited for our own requirements; but, for a little counter criticism, I venture to think, respecting the clever mechanical line ear of his own design, that in its present form trouble would sooner or later occur, because of the inadequate amount of insulation of the conductor from the span wire which he has provided, using only a rubber tube bushing.

Mr. Holroyd Smith's trolley is ingenious, but its position necessitates the car always travelling in one direction (that is, if it is the intention for the collector to engage with the conductor, behind the passengers); whereas the pivotal form of

trolley allows it to be swung round, and does not necessitate a loop being provided in the track at the termini. Mr. Lundberg.

The lightning arrester is an important piece of apparatus, and I trust the apparatus exhibited overcomes the shortcomings of earlier appliances and is more of an actual protection, as these were not always efficacious in preventing damage to the electrical apparatus during a storm. From the considerable improvements which have been effected in trolleys and supports for the conductors, one is led to think that the days are over when it was no uncommon sight to see an *employé* on the roof of the car taking it home by means of a flexible wire held in contact with the conductor, the trolley having become disabled.

In some cases this was caused by the flange of the wheel having worn through, and the spoked trolley wheel exhibited would overcome this defect.

Accidents to trolleys, such as I have seen, would prove disastrous if they occurred on our double-decked cars with passengers on top.

A word of praise is due to the originator of the carbon brush for street railway work. Before the adoption of this material, commutators and metallic brushes were a source of continuous trouble. The extra resistance is certainly against its adoption, but this has been reduced by increased cross section and coppering.

I noticed amongst the various American appliances a carbon brush stranded with copper, in order to give it increased conductivity. The advantages gained by their use more than balance the increase of resistance, and wear on the commutator is reduced to a minimum.

In thanking Messrs. Wilkinson, Blackwell, Dawson, and Preller for having given us such a fund of useful information, I regret that little mention is made of the work of pioneers in this branch of the industry.

I heard with pleasure Mr. Holroyd Smith (a pioneer himself whom we are all proud of) express his indebtedness to Mr. Sprague.

Perhaps at a future date the pioneer efforts of other American engineers—notably Messrs. Daft, Bentley, Knight, and Van Depoele

Mr. Lundberg. —will come in for recognition also, when our own engineers have profited by their efforts.

Mr. Geipel. Mr. WILLIAM GEIPEL [*communicated*]: It is difficult to understand how the welding of the rails into one length does not cause more difficulty than we gather from Mr. Wilkinson, for the difference in length during summer and winter may be as much as 3 feet per mile. It is possible that the particular line—*i.e.*, the West End Street Railway—contains many curves, which would, of course, obviate the buckling or breaking that would undoubtedly take place in long straight lengths, owing to expansion and contraction. We have had experience of this difficulty on our English railways, where too little clearance has been left between each length of rail.

The expression "crowding out," or "shedding," of current at the rail-bonds seems to me to be misleading, for it does not follow, if a high resistance is introduced by a particular bond or bonds, that the current necessarily goes to earth at such points. Is it not purely a question of potential difference and resistance? If one end of the rails is at earth-potential, then the other parts are different in potential according as the resistance, and magnitude of the current; and the current will leave at those points in the rail which are either highest in potential or where the earth offers least resistance—as, for example, where a gas or water pipe runs near the rail.

Mr. Wilkinson recommends a maximum current-density in the bond of 2,000 amperes per square inch. Mr. Parshall speaks of a contact area 20 times that of the bond. Is not the former cutting it too fine? and, with regard to the latter, is a ratio of 20 not unnecessarily large? Messrs. Blackwell and Dawson find that copper deteriorates quickly, which points to the undesirability of cutting the area of the bond so fine.

Again, such a high density as 2,000 amperes per square inch does not appear to involve the best arrangement on economical grounds. In electric lighting in this country a lower density is adopted, and as the hours of use in traction work are probably greater a still lower density would appear economical, more especially for bare copper. I would suggest a density of 500 amperes per square inch as the limit.

I quite agree with Mr. Robinson in his remarks upon the statement made by Mr. Preller regarding the superior governing of slow-speed engines; and I am surprised that Mr. Preller has not experienced much greater difficulty in the governing of the turbines, which must be incomparably slower than either high- or low-speed engines, unless the governors in use were very different to those used on turbines in this country. I have had experience of this at Worcester with 4 ft. 6 in. diameter turbines, where I find the governing of the engines very much more rapid; with sudden variations in load the turbines are quite incapable of coping. Perhaps Mr. Preller will tell us how this difficulty is got over. Mr. Geipel.

Mr. Preller, in advocating alternate current, and Mr. Parshall, in depreciating its use, have both omitted one very important point in their favour, as compared with continuous currents: it is, of course, the abolition of the commutator. I agree entirely with the views of Mr. Preller; it seems to me, if we are to work long railways without an unnecessary multiplication of generating stations, that the alternate current promises the best solution of the difficulty, as it is so easy to feed by high-tension feeders, transforming to a suitable low pressure at frequent intervals along the line.

Mr. B. M. JENKIN [*communicated*]: Mr. Wilkinson, in comparing the advantages of the double- and single-trolley systems, has suggested, as a means of getting rid of the injurious earth currents usual in the latter system, the use of insulated return feeders from the rails, connected direct to the negative terminal of the dynamos at the station. He says, on page 633, that by this means the "current will be kept *within* the rails and "return feeders," and that electrolytic corrosion will only occur at bad joints in the rails, "and not on underground pipes and cables;" and lower down on the same page he says that a supplementary wire, if properly increased in section as it approaches the power station, "would do nearly as well as insulated feeders, provided "the connection from the rails to the generators were made at the "nearest point to the power station by insulated cable." He therefore only considers the return feeders as a means of increasing the Mr. Jenkin.

Mr. Jenkin. section of the rails; the insulation on the cables from the last rails to the station preventing earth currents.

So far in the discussion this point has not been raised.

In order that the current may run "within" the rails, there must be a D.P. between two points in the rails, and therefore also between the earth at these two points; and there will therefore also be a current in the earth, or, in plain words, the earth is a shunt on the rails as a whole, as well as on the joints of high resistance. And for any given D.P. between two points along the track the current will be divided between the rails and the earth directly in proportion to their relative conductivities. I do not see how insulation on the return feeder can affect this.

If at any point along the track the relative conductivity of the two paths alters, the current must perforce redistribute itself. Thus at a bad joint the resistance of the line increases for a given length, and more current goes by the earth path and less by the bond; and, similarly, if there are bad joints in the pipes in the earth, part of the current leaves them for the rails. For as long as the rails and the earth are in contact all the way, we must have the same drop of potential in the two, and if for any length the resistance varies in one and not in the other, the current readjusts itself to keep the drop the same in both.

Similarly, if the current increases at any point due to the passing of a car on the rails, a share of it will go by the earth path, and at all these points we shall have electrolytic action on the rails or pipes. The doing away with the earth plate at the station and the substitution of the insulated return from the last rails may save the pipes near the station, but it is at the expense of those near the last rails, as it is converting these last rails into an earth plate.

The only way in which we can get rid of the earth currents entirely when using the earthed rails in the circuit is to maintain all parts of the rails at the same potential. This could only be done by the use of an infinite number of insulated return feeders, which, of course, is impossible. But we can approximate to it by the method commonly used for L.T. two-wire lighting mains, which is to keep the points where the return feeders leave the

mains, or rails in this case, at the same potential, and to put these points close enough together to prevent the drop in the rails due to the flow of the current from the cars to the return feeder points being more than a certain amount found not to cause earth currents large enough to do serious damage to pipes, &c. This, of course, cannot be done if we use a supplementary wire between the rails. Mr. Jenkin.

The Board of Trade have fixed this difference of potential at 7 volts. This is apparently a fixed quantity, and does not depend on the length of the line.

If we work out the actual drop occurring in the rails, due to the current flowing from the cars to the rails, taking the return feeder points as half a mile apart, and the other conditions as given by Mr. Wilkinson in his example on page 577 of his original paper—namely, a three-minute service, a speed of $7\frac{1}{2}$ miles per hour, an average current of 50 amperes per car, and 70-lb. rails, leaving out branch lines—it comes to about one-fourth of a volt in ordinary running, or, in the case of cars starting simultaneously, it might be half a volt.

This shows that we might increase the distance apart of the feeder points, and we do not reach the allowable limit of 7 volts until they are about four miles apart—that is, assuming the cars are running steadily at 50 amperes each; but, in order to allow for the variation due to the starting, &c., we should probably find the limit was about half this, say two miles—*i.e.*, as long as we use the rails only to collect the current for the return feeders.

Or we might leave the return feeders spaced half a mile apart and send some of the current back by the rails, by keeping the return feeder point nearest the station 7 volts below the most distant one. It would only take about ·38 amperes per rail to give us this drop.

There are two distinct ways in which we can regulate the potential of the rails at the return feeder points—

1. By adjusting the resistance of the return feeders so that they all have the *same drop* when equally loaded (*i.e.*, considering a track with cars equally spaced and the feeders collecting from equal sections). This, of

Mr. Jenkin. course, is the usual plan adopted for L.T. feeders for lighting mains. The return feeders are then run in parallel at the station off dynamos in parallel.

2. The other way is by working the return feeders at the *same density*, and therefore with a drop depending directly on their length, and either run off separate dynamos at different voltages at the station, or by some device such as is known in the States as "boosters."

This density would, of course, be such as to give the least total cost of transmission, namely, that which makes the cost of energy wasted equal to the depreciation and interest on the copper laid.

If we take the cost per kilowatt-hour at 2d., the cost of the return feeders (armoured cable) at 13s. per yard per 1 square inch section, interest and depreciation at 5 per cent., and consider the feeders as working 12 hours out of the 24 at this load, the most economical density works out at about 190 amperes per square inch. I do not, of course, give this as the right figure, but only to show the sort of difference between the two ways of working.

If we consider a line five miles long, starting a quarter of a mile from the station, and arrange all the return feeders to work at the above economical density, the longest return feeder (five miles long) will have a drop of about 42 volts, and the shortest (a quarter of a mile long) about 2 volts,—which means that the booster would have to raise the volts on the longest return feeder 40 volts before the two were put in parallel on the negative terminal of the dynamo; or, if we consider the earth at 0 potential, it would have to raise the current from − 40 to − 2, the potential of the negative terminal of the dynamo.

If we arrange all the return feeders in the other way—*i.e.*, to have the same drop—and leave the longest return feeder the same as in the above case—*i.e.*, with a 42-volt drop and a density of 190 amperes per square inch—the shortest return feeder must also have a drop of 42 volts, but on a length of only a quarter of a mile, which gives a density of 3,800 amperes per square inch. Even if we allowed the difference of 7 volts between the two—*i.e.*,

bringing some 150 amperes back by the rails—we should have a drop of 35 volts and a density of 3,150 amperes per square inch. This being too large, we must either put resistance in series with the shorter return feeders, or increase the section of the longer ones so as to reduce the drop. Thus, if we take the limit of density for the shortest return feeder at 1,000 amperes per square inch, we have a drop of 11 volts on the quarter mile, and, allowing the 7 volts difference, only 18 volts on the longest with a density of 83 amperes per square inch. This means more than twice the quantity of copper in the longest feeder that is given by the economical density. Mr. Jenkin.

There is not time to go into difference of cost of transmission in the two cases. But it is clear that, whichever way we alter the return feeders—either by increasing the copper and decreasing the C^2 R loss, or *vice versâ*—the cost of transmission will be more than by using return feeders all working at the same economic density throughout.

My object in raising this question of return feeders when the rails are a part of the circuit is to point out the necessity of designing this part of the circuit in a way that will comply with the regulations and conditions that exist in this country. In the States the return half of the circuit was apparently never considered until they found out the damage that was being done to the pipes and cables.

All the devices of rail-bonds and supplementary wires that we have heard so much of are really only, as it were, make-shifts to try and mitigate some of the evils due to a radically bad design. Mr. Parshall has told us of a bond designed to work satisfactorily at 1,000 amperes per square inch. Supposing the bond to be of the same conductivity as the rail, this density gives a drop of 44 volts per mile on the track; so that this bond would only be suitable for a track some 300 yards long, as with that length we should have reached our 7-volt limit. In discussing all these American designs, we must consider them from the point of view of their application in this country, and not from the point of view of their merits as remedies for evils due to bad design.

If we use the single-trolley system, we must have the rails as

Mr. Jenkin. part of the circuit, and they must be kept at nearly the same potential throughout, which necessitates either a large capital expense in laying down feeders which are too big for the current they have to carry (or the alternative of a constant large $C^2 R$ loss), in order to run the return feeders in parallel at the station, or it necessitates the use of boosters or other machinery, and the consequent complication in case of breakdowns.

If we use the double-trolley or three-wire system, these difficulties disappear, as we can then run the return feeders at the most economical density, and run them in parallel at the station; the difference in potential along the negative trolley wire being exactly similar to that on the positive, and only affecting the pressure attainable at the motor terminals, and the speed to a certain extent.

In comparing the single-trolley with other systems, we must consider the above points, as they will alter its comparative advantages and disadvantages to a great extent from those which exist at present in the States.

Mr. Wilkinson. Mr. H. D. WILKINSON (in reply): Dr. N. S. Keith has given some details of a mountain electric line in California which are of special interest in this branch of electric traction. Besides the application of electric haulage for the counterbalanced cars on the steep-grade section, there is an interesting application of electric transmission of power in lifting water to the summit and diverting its course to where a fall is required.

I fully endorse the feelings of appreciation expressed by Mr. Mark Robinson towards the many American engineers who have generously placed in my way facilities for gaining information for this paper, and especially towards Mr. R. W. Blackwell and Mr. Philip Dawson for the very complete collection of up-to-date apparatus which they have placed before us in connection with their paper.

I am very glad to have the opinion of Mr. H. F. Parshall, who has been associated with electric tramway work in the States for so long a period, on the various points raised. I think the most suggestive remark made by Mr Parshall is that referring to the use of motor transformers. These machines I

saw in operation at the Columbian Exposition. The high-tension alternating current was put into the armature on one side in the ordinary way by a pair of brushes bearing on a pair of rings, and a direct current at low tension was collected by four brushes from a commutator at the other end of the shaft, the commutator being connected to the same armature—that is, one winding doing for both motor and dynamo. The multipolar field was excited in shunt off the commutator side. The core losses in this combination are exceptionally small, and a high efficiency of transformation is obtained. With such sub-stations as could be worked by these machines from a central high-tension alternating station, many miles of line could be economically supplied. The full advantage of return feeders also could be utilised without these assuming inordinate lengths and sections, because they would simply return to the sub-stations. It is gratifying to hear from Mr Parshall that such systems are being successfully carried out. Mr. Wilkinson.

In reply to Captain Sankey, I should say that, as far as my experience goes, fractures of fly-wheels have been mostly due to excessive centrifugal force, and I am not aware that any have been directly traced to the strain on the periphery when a dynamo driven by belt has suddenly pulled up. I am in accordance with Captain Sankey in his statement that the energy is dissipated in the belt. The belt, by slipping, takes up the energy of the fly-wheel in the same way as the band round a brake pulley takes up the energy in that pulley. Yet fractures do occur in the spokes of brake wheels at times, and it is conceivable that the strains, although not sufficient in a well-designed fly-wheel to directly cause fracture, may, after frequent occurrence, cause such a set in the molecules in the direction of stress that when the direction of strain is reversed in racing the metal is more liable to give way.

I am much gratified that this line of criticism taken up by Captain Sankey has led him to go into the question of crank-shaft strains in engines directly coupled to dynamos, and to give us the actual stress in tons per square inch on a crank-shaft suddenly pulled up. The curves for both single- and double-acting

Mr. Wilkinson. engine crank-shaft stresses corresponding to various angles of stoppage after a sudden load are of great practical value, as they show that the utmost conceivable strain due to short-circuit of a direct-coupled engine and dynamo is well within the elastic limit of the steel crank-shaft. This shows that the advantages of coupling engine and generator shafts rigidly together, claimed by Mr. Parshall, is in no way detracted from by any possibility of the engine crank-shaft coming to grief under sudden loads, even with very moderate fly-wheel protection. The conclusion is that with proper regard to the mechanical strength and insulation of the armature the direct-coupled set can be made perfectly safe against any short-circuit.

In reply to Mr. B. M. Jenkin, I would say that in the statement that the current will be kept *within* the rails and return feeders by the latter being *insulated*, I alluded to the current which otherwise (namely, when return feeders are not used) would find direct paths through the earth to the power station as well as by the rails. This is the current we have to consider, as it forms no inconsiderable amount when metallic earth paths, such as pipes and cables of low resistance, are present between the power station and different points on or near the line. The shunt path through earth on the rails as a whole must, of course, exist in any system where the rails are not insulated, even in the three-wire system; but in face of the rail conductivity as compared with that of the earth it appears unlikely that any appreciable current flows through the earth as a shunt on the rails unless at bad joints in the rails, as stated. But, whatever the earth shunt current may be, it becomes something extremely small when the drop in the rails is reduced by the use of return feeders. This current is not, of course, affected by insulation on the return feeders. On the other hand, as Mr. Jenkin's remarks bear out, the return feeders used for establishing points on the rails at, or nearly at, the same potential must be insulated. This is precisely what I have advocated in Stage 5 of my supplementary paper. The return current, instead of flowing along the rails and by the earth to the power station, is collected towards the feeding points

in virtue of their connection to the negative poles of the generators, the potential of which, when the feeders are insulated, is below that of the earth. Mr. Jenkin has gone a step further, and discussed the relative advantages of feeders on the basis of uniform drop or uniform density. The boosting up of the return feeders necessary to run generators in parallel when the former are on a uniform density basis introduces another, or several other, undesirable additions to the regulating apparatus. On the uniform drop basis, Mr. Jenkin shows a very great disparity between the densities on the nearest and furthest feeders, allowing for the limit of 7 volts drop on the rails. He finds that, with a density limit of 1,000 on the short feeder, the density on a five-mile feeder must not exceed 83. If the first limit were raised to 1,500 the latter would still be as low as 114, keeping the drop of 7 volts on the rails constant. Mr. Wilkinson.

The amount of copper required for these low densities and long lengths (in accordance with the rule for fixed drop on the rails for any distance) renders the cost of feeders prohibitive for more than a few miles, and points to the desirability of using high-tension alternating currents to drive commutating dynamos at feeding points, as Mr. Parshall informs us is now being successfully carried out in the States. Even a smaller drop, but limited to a given amount per mile of rail, would considerably reduce the cost of long-distance feeders by making it possible to work them at a higher density. As the limit is now fixed, the greater the length of line the less, proportionately, must be the current returned by the rail.

Regarding the point raised by Mr. Jenkin as to the use of the supplementary wire, I had in view cases where currents passing by earth would find no metallic pipes to operate upon, such as would exist in lines crossing commons or other open spaces, or communicating between small towns. Under these circumstances I think the earth path may be favoured and metal saved, especially where it is convenient to place the power station one or two miles from the nearest point.

Mr. Jenkin has supposed me to confuse increase of rail conductivity with a return feeder; but I think the above

Mr. Wilkinson.

explanation will make it clear that the two methods of return are not bound to be considered similar because one is stated to do nearly as well as the other in certain cases.

In reply to Mr. Arthur E. Childs, I am glad he has pointed out some of the particular conditions in which an earth path is satisfactory, and especially for information on the methods adopted at Williamsport and Middletown. The only logical inference, however, that can be drawn from Mr. Childs's remarks on Mr. Rostron's experiments appears to be that the current passing to earth by the plates on the line found a better conductivity in pipes than the earth, which accounts for the current received by the station earth plate being so much less than the total current passed into the earth plates. I am much gratified to hear from Mr. Childs that electric traction has extended to such an extent in the Quaker City.

I am sure the members of this Institution, as well as myself, are very glad to receive a communication from Mr. Alfred Dickinson on the subject under discussion. Mr. Dickinson is well known as the designer and constructor of the trolley line in South Staffordshire; and I, in common with others, am exceedingly pleased to have the advantage of his views on the systems under discussion.

As regards cost of construction of overhead and conduit lines, my estimates were based on American practice. For instance, taking the conduit system, the actual cost of the 3¼ miles of single track laid in Washington was £28,600, including conduit, rails and permanent way, cables, power station, generating plant, land, and rolling stock. Including all these items, therefore, and everything that goes to make a complete equipment, the total cost was £8,800 per mile of single track. The track, rails, conduit, and cables for which I have estimated constitute, therefore, only a portion of this expenditure. There would be about 50 tons to the mile of 32-lb. steel slot rails, 100 tons of 70-lb. steel running rails, 160 tons of cast-iron yokes and shields, 7 tons of fish-plates, bolts and nuts, costing approximately £2,250 delivered; the conductors and insulators fixed would cost about £280; gear for taking up expansion, £120;

manholes, £350; leaving £1,000 for excavating, laying, and repaving. Mr. Wilkinson.

As Mr. Dickinson points out, the tortuous character of roads in this country renders construction work more difficult than on the straight American roads, and the conditions as to track-laying and repaving imposed by large local authorities are more exacting. The item of paving alone as done in this country is a very large one, costing in some cases as much as 10s. to 12s. per square yard, and bringing the cost of the 8-foot way to £2,300 to £2,800 per mile. This affects both overhead and underground lines, and an extra amount has to be added in estimates for English lines depending upon local regulations in this respect. Excavation also costs somewhat more in this country owing to the better metalling of the roads. The amount to allow depends entirely upon the conditions in each particular case, but I think the work can be done well in a conduit system without going to the high figures mentioned by Mr. Dickinson. Mr. Dickinson gives us a record of the fewness of short-circuits on the South Staffordshire line, which is a source of gratification as evidence of good design and material put into the work.

I am pleased that Mr. Dickinson has told us the chief points of advantage in the side trolley wire, with which I am fully in agreement, having carefully followed the constructional details at the time the line was first started. With regard to fire-escapes, I think it has long been a necessity to have the entire gear on four wheels, capable of being drawn quickly by horses to the scene of a fire, instead of the present vertical form pushed by hand. I have witnessed fires in the city of Chicago where the fire-escapes were drawn by horses, and arrived at the scene simultaneously with, if not before, the engines. Once drawn up at the curb, it took but a few seconds to raise the ladder to any point on the building. Mr. Ferranti has also ably discussed this question; and I am sure that the adoption of such a system would be a great safeguard to the community at large, and at the same time remove one source of prejudice against the overhead trolley.

I am indebted to Mr. G. C. Lundberg for detailing his

Mr. Wilkinson.

experience of the Bentley-Knight overhead double-trolley system in Allegheny, Pa., more especially as I have not been able in the limited scope of my paper to afford myself the pleasure of sketching the work accomplished by America's great pioneers in this field. But the names of Messrs. Daft, Bentley, Knight, Van Depoele, and Sprague are well known in our country, and to a great extent also the pioneer work they accomplished, and they can never cease to receive from us the recognition they so deservedly merit.

In reply to the point raised as to the collector on the Washington cars meeting with obstructions in the slot, this is taken care of by a cleaning knife carried by the car in advance of the collector, and the latter is stong enough to carry away anything that is passed by the knife.

In reply to Mr. William Geipel, I think one cause why more difficulty has not been met with in the expansion of welded rails may exist in the fact that the area of a tram rail is for the most part buried in earth, and thus surrounded by a heat-conducting medium, whereas the rails on our steam roads are dependent almost entirely upon radiation for the dissipation of heat. But should difficulties arise (and, as Mr. Lundberg has remarked, the extreme temperature ranges in America test such a system in the severest possible way), it will only slightly increase the cost of welding to make two welds to a joint instead of one, and allow a loop for expansion, the rails not being butted. Thus the joint will be perfect, and expansion provided for.

The question of current leaving the rail and going to earth depends, of course, upon the comparative resistance of rail and earth between the points considered. If the conductivity of the earth is increased by rains, or the conductivity of bond joints reduced by age or electrolysis, the current going to earth is increased. Again, if the current returned by the rail is increased, say by the addition of more cars, or extending the line, the current in the rail and the earth path is simultaneously increased. This increase of density in the rails and bonds is therefore accompanied by larger earth currents, as well as increased volt loss and heating in the bonds. In advocat-

ing that the density in the bonds should not exceed 2,000 amperes per square inch, I did not intend to advance this as the most economical maximum limit, but a limit that would prevent heating at bond joints and undue electrolytic action thereon, the effect of which is to increase the resistance and send more current by the earth. The expressions "crowding out" and "shedding" of current, to which Mr. Geipel, with some reason, takes exception, were intended to express concisely the effects described; but I do not think it necessary to vindicate such terms so long as it is understood that the effects they were intended to describe follow the law of derived circuits. Mr. Wilkinson.

However much return current we have to deal with, it is certainly not only more economical, as Mr. Geipel points out, but also safer as regards earth currents, to keep down the density in the rails and bonds. Without stating any economical limit, I advocated the use of insulated return feeders for this purpose, and, considering the regulation limit of 7 volts drop on the rails, which keeps the current returned by this path within small limits, I should consider it unadvisable to put bonds of such small sectional area as would much exceed the density suggested by Mr. Geipel. If, on the other hand, the current returned by the rails amounted to thousands of amperes, as in America, instead of a hundred or two, I should say that a great deal of the trouble now going on would be eliminated if the density were kept down to 2,000 at the very outside.

I am much indebted to Mr. Holroyd Smith for describing some of the ingenious overhead appliances he has devised, and I am gratified to learn that Mr. Smith's experience bears out the conclusions I have arrived at by observation of American practice. As regards the kind of trolley pole for top-seated cars, I think that the simple American form is not prohibitive, as stated by Mr. Smith; but, at the same time, the placing of the pole at the back does not altogether effect the object desired, as the trolley wire must be shielded if centrally suspended. With regard to Mr. Smith's remarks on the American conduit system described in my paper, I think the matter is best looked at from the practical point of view. It must not be possible to cause interference of

Mr. Wilkinson. traffic by rain, snow, street sweepings, obstructions in the slot, or changes of temperature, and the travelling contact must be as frictionless as possible to prevent loss of power and excessive wear of the conductors, while at the same time an unintermittent contact is maintained. The details of the Washington line appeared to me to be very favourable to these conditions, and I judged that the members of this Institution would like to be made aware of its chief features.

Major-General Webber has, I think, touched upon a useful field for storage batteries in lines of small gauge and infrequent traffic, where it might pay to put down a small charging plant, instead of one of sufficient power to work the line direct.

I have listened with great interest to the remarks of Mr. F. F. Robinson, Mr. Lea, Mr. McGraw, Dr. S. P. Thompson, Mr. Ferranti, Mr. Carruthers Wain, Mr. Sharpe, and Mr. Dallas. The remarks made by the President of the Tramways Institute give us information of what is being done and experimented with in this country, and are very suggestive of future developments. The wishes expressed by Mr. Carruthers Wain with reference to the Board of Trade Conference cannot but instil confidence as to the readiness of the tramway companies to adopt improved methods of working.

In conclusion, I can only express my gratification at the reception you have given the papers presented on this subject, and the hope that they may prove to have been the means of adding an interest and stimulus to the development of electric traction.

Mr. Dawson. Mr. P. Dawson (in reply): In replying for Mr. Blackwell and myself, it is my pleasant duty to express how much indebted we are to you, both for the courteous hearing and the kindly criticism you have accorded us.

As Mr. Mark Robinson has justly said, the financial aspect of electrical traction is of paramount importance.

It may be interesting to give some results obtained in America and on the Continent. From a careful analysis of a large number of electric railway accounts, we find that the average working cost per car mile, exclusive only of interest on capital, is approximately

6½d. in America and 5½d. in Europe, and that the ratio of working expenses to receipts in both countries is approximately 60 per cent. Mr. Dawson.

In contrast with this, we have the working costs per car mile of the horse and steam tramways as being 10d. per car mile, and the ratio of expenses to receipts over 80 per cent.

We have prepared a comparative table of American and European electric roads, and a summary showing the probable advantage to accrue to the English tramway investor when electricity is substituted for horse and steam as a motive power:—

——	Name of Electric Line.	Ratio of Working Expenses to Receipts.	Total Working Cost in Pence per Car Mile, Interest on Capital alone excepted.
		Per Cent.	
U. S. A. ..	Pittsburgh, Pa.... ..	71·1	6·12
" ...	Chicago, Ill. ...	40·0	6·80
" ..	Rochester	48·62	5·53
England ...	Liverpool Overhead ..	73·0	4·35
" ...	City and South London	64·0	5·31
" ...	Bessbrook, Newry ...	...	3·97
" ...	Roundhay Road, Leeds	...	5·55
" ...	South Staffordshire Electric	...	4·06
" ..	Guernsey, Channel Isles	54·45	6·22
Germany ...	Halle	54·50	2·62
" ..	Frankfort-on-Main ...	70·0	4·60
Switzerland	Murren	50·0	4·00
France ..	Marseilles	60·0	6·68

Mr. Dawson.

Name of Horse Tramway.	Ratio of Operating Expenses to Receipts	Total Cost in Pence per Car Mile.
	Per Cent.	
All London Tramways ...	82·7	9·8
Birmingham, Midland ...	81·22	13·22
" Central ...	76·79	9·96
Dublin United	73·80	9·77
Dundee	73·75	10·78
Leicester	83·78	9·80
Sheffield	79·85	9·95
Newcastle and Gosforth ...	90·51	11·25

The following summary of 73 English horse tramways has been worked out from "Duncan's Tramway Annual" for 1893:—

Number of Lines.		Ratio of Operating Expenses to Receipts. Per Cent.
14	... ...	75 to 80
13	... ...	80 " 85
13	... ...	70 " 75
8	... ...	90 " 95
8	... ...	85 " 90
4	... ...	95 " 100
4	... ...	65 " 70
4	... ...	60 " 65
2	... ...	100 " 105
2	... ...	55 " 60
1	... ...	40 " 45

The following summary of 45 English horse lines is compiled from the same authority:—

Number of Lines.		Working Expenses in Pence per Car Mile.
14	... ...	8 to 9
12	... ...	9 " 10
8	... ...	10 " 12
5	... ...	12 " 14
3	... ...	7 " 8
2	... ...	6 " 7
1	... ...	5 " 6

In the State of Massachusetts, U.S.A., the capital invested in street railways in 1888 (the year preceding the introduction of electrical motive power) was £2,251,602, and the average dividends paid were 5·74 per cent. By the end of 1893 the capital invested had risen to £5,349,272, and the average dividends to 6·63 per cent. Mr. Dawson.

In 1888 the average ratio of operating expenses to receipts was 81·07 per cent. This had decreased in 1893 to 69·26 per cent. The net earnings in 1888 were 2·78 pence per car mile. In 1893 they were 4·82 pence, or nearly double. The net earnings per passenger carried in 1888 were 0·48 pence. In 1893 they were 0·78 pence. The total track mileage in 1888 was 534 miles, all horse or steam. In 1893 there were 874 miles of track, of which 711 miles were electric. The total capitalisation per mile of track was £11,000 per mile in 1893.

It must be borne in mind that the introduction of electricity virtually meant the entire reconstruction of many existing roads, and heavy sums being paid to obtain extended franchises; besides which, the first electric roads were largely experimental, and were practically entirely re-equipped.

It would seem that these figures should carry conviction.

Dr. Keith, to whose exertions is due the existence of the American Institution of Electrical Engineers, an association closely patterned upon this Society, has given us valuable memoranda of his experience in steep-grade traction. As supplementing his remarks and the interesting paper by Dr. Preller on this specific department of traction work, we would say a few words.

To show what electric motors can do on gradients, we have put up the profile of a line at San Francisco, visited last summer. The road has in all five miles of double and seven miles of single track. Thirty motor cars are operated. The power-house plant consists of two 550 triple-expansion condensing engines of the Corliss type, driving by ropes a counter-shaft to which the generators are belted. A steam pressure of 150 lbs. to the square inch is used. Eight per cent., 9 per cent., and 10 per cent. grades are long and frequent, and occasional grades of 11 per cent. and 14

Mr. Dawson. per cent. are encountered. From tests given to us at San Francisco by Mr. Babcock, chief engineer of the General Electric Company in that city, the following figures are quoted:—The car experimented with was 26 feet long over all, and equipped with two motors of the "W.P. 50" type, and rated at 15 H.P. each. The total weight was, approximately, 8 tons. On a 7 per cent. grade, the current varied between 90 and 130 amperes, at a voltage of 505 to 445 volts. On an 11 per cent. grade, the current varied from 100 to 160 amperes, and the voltage from 450 to 395 volts. The average speed, stoppages included, on a run of $5\frac{1}{8}$ miles, was $8\frac{1}{4}$ miles an hour. The maximum electrical horse-power taken from the trolley wire by the car was 91·14 E.H.P., and the average E.H.P. during the trip was 47·70 E.H.P.

On the Metropolitan Electric Street Railway of San Francisco there are several 11 and 12 per cent. grades, and one of 13·82 per cent., all of which are easily mounted by the electric cars by natural adhesion alone.

At Portland, Oregon, the electric cars ascend several gradients of 10 and 12 per cent.

At Seattle, Washington, grades up to 17 per cent. are surmounted by electric cars. In this case, however, a counter-weight running in a trench under the centre of the track is used.

This counter-weight is mounted on a small truck attached to an endless wire rope, supported on small carrying pulleys, and running over terminal pulleys at each end of the grade, one of which pulleys is mounted on a tension car which takes up the slack in the rope. A car descending the grade is attached to the cable through a slot in the roadway, and pulls the counter-weight up. The weight is held at the top till an ascending car is attached to the cable, when it is allowed to descend, and helps to haul the car up.

There are any number of electric roads operating long grades of from 5 to 10 per cent., and paying well.

In fact, many American electric roads would come under the title of steep-grade traction.

A pioneer in electric traction work like Mr. Holroyd Smith

cannot but give us valuable information, and the exhibits he has shown are most interesting. It is a curious fact that the original desire of American engineers was to perfect and put in operation a conduit system, and that, starting with the sub-surface conductor, the process of evolution has resulted in the overhead trolley-wire system. We much question whether the Buda-Pesth conduit, so much discussed of late, has any features which entitle it to rank as the equal of the conduit system which was finally discarded in the United States in 1889. Where a conduit is advisable, it is our belief that the cable system possesses greater advantages than electricity, and we have yet to find any proof that a thoroughly workable and permanent electric conduit tramway construction has been developed except at practically prohibitive expense, and at the cost of disfiguring the streets and inconveniencing the public to a much greater extent than can possibly result from the trolley-wire system. Mr. Dawson.

General Webber and Professor Silvanus Thompson have called to your attention the economic, social, and hygienic side of electric traction. It is undeniable that one of the most pressing needs of the present day is the extension of rapid transit to such a degree as will enable the possible residential zone surrounding our great cities to be greatly increased. From every point of view it is of overwhelming importance that our great working class be given facilities which will enable them to live in accessible surburban districts, and which will lessen the ever-increasing overcrowding of our centres of population.

The electric tramway has effected this object in America to the fullest extent, and has brought the blessing of pure air and healthful life to thousands to whom it first became attainable through the trolley wire and the motor car.

That the agricultural, mining, manufacturing, and fishing districts are clamouring for light railways you all know. It is manifestly absurd that regulations designed for the government of trunk line steam railways should stand in the way of their being granted the relief they need.

Mr. Carruthers Wain is fighting a good fight in the interest of electric traction, or, rather, of that system of mechanical

Mr. Dawson.

traction which can, in a fair field, prove itself the best. It certainly is the duty of the members of this Institution to aid him in every way which may lie in their power.

Mr. Ferranti has remarked on the possible obstruction offered to fire-escapes were the trolley wire brought into general use. Curiously enough, it never occurred to the American mind that the proper way to carry a ladder was in a perpendicular position; and I question whether any of us would think of that method if we were called upon to transport one for any distance. In America, fire is a danger of much more moment than it ever has been or ever will be here; but running a ladder through the streets on end was never heard of there, even before the days of the first elevated wire.

While no such extended use of electric motive power has yet been made in Europe as is the case in America, the results so far attained are by no means trifling. At present there are, roughly speaking, nearly 1,300 cars propelled by electric motors, 500 miles of trolley wire already in use, and 25,000 steam horse-power in electric tramway station plant. Contracts are already in existence for 1,000 additional motor cars, 400 more miles of track, and 18,000 steam horse-power in station. These figures are approximate, but they are very close approximations, and based upon exceedingly careful investigation. If we are not greatly mistaken, electric traction will progress on the Continent during the next year or so almost as fast as it has in the United States. The contracts now signed for new work in Europe are practically equivalent to all that has heretofore been done on this side of the Atlantic.

It is an error to refer to motor cars as being inapplicable to narrow and crooked streets. While it is undoubtedly true that many American cities rejoice in broad avenues, the electric tramways run through many narrow streets as well. In the old Continental towns which now have adopted the trolley system, the lines run through many streets as narrow and tortuous as are to be found in any English town. In one notable instance—at Essen—the tramway passes through streets 13 feet wide between house fronts, and only 11 feet wide between curbs.

Mr. Dawson.

The statement made by Mr. Parshall as to the entire safety of a speed in crowded streets of six miles per hour, and of 15 miles per hour in residential and suburban districts, is wholly correct. No serious protest has ever been made in America or on the Continent against such speeds, and accidents there are less frequent than in European cities where horse traction is used.

The torque curve shown of a three-phase induction motor is extremely interesting, and proves that for the present, at any rate, this type of motor is useless for tramway work. As Mr. Parshall points out, however, alternating currents will be used to great advantage in transmitting the required energy for long distances. When it has arrived at its destination it can then be transformed into direct current for working the tramways. This is now being done on a very large scale at Portland (Oregon), and the best results are expected.

Mr. Parshall has also given us some exceedingly valuable figures for ready reckoning. His experience as the designer of the electric power plant employed so successfully in the greatest tramway stations of the United States enables him to speak with authority.

We are glad that Mr. Lundberg has taken part in the discussion, and given us the benefit of the extensive practical experience with line construction which he acquired while working with the pioneer American companies. No one could speak from a more thorough acquaintance with the early difficulties encountered, and the manner in which they were, little by little, overcome.

In the course of a few remarks made before this Society in 1892, during the discussion of a paper on traction read by the late Anthony Reckenzaun (himself one of the first to devote attention to electrical motive power), Mr. Blackwell called attention to the carbon brush mentioned by Mr. Dallas, and to the debt owed to Professor Forbes, its inventor, by all electric tramway operators.

The cordial invitation to visit America extended by Mr. McGraw is worthy of acceptance, and we speak as having experienced his hospitality at former Street Railway Conventions.

Mr. Dawson. Electricians owe a debt to Mr. McGraw, and to his *Street Railway Journal*, for having consistently urged the advantages of electric traction, and for having developed a series of publications which have been of the greatest possible practical value to manufacturer, constructor, operator, and investor.

We believe it to be impossible that an engineer who now visits America (or, for that matter, the recent Continental installations) can fail to be impressed by the fact that England cannot afford to disregard longer the wonderful results that have been attained, or to recognise how vastly the demonstrated advantages of electrical traction outweigh all the possible objections that can be urged to its extended introduction.

Dr. Preller. Dr. Du Riche Preller: It may be convenient if I reply *seriatim* to the more important points which have been raised in the course of the discussion.

1. As regards Mr. Lea's inquiry whether I had instituted a comparison between electrical and steam working on rack railways, I need only refer to the tabulated comparison which I made in *Engineering*, vol. lvii., p. 505 (20th April, 1894), of the cost of construction and working of the Mont Salève (electric) and the Glion and Rochers de Naye (steam) rack railways, and of which the following figures may serve as an abstract :—

	Salève (Electric).	Glion (Steam).
Length of line	3·6 miles ...	4·8 miles.
Steepest gradient	25 per cent. ...	22 per cent.
Cost of construction and equipment	£16,200 ...	£17,600 per mile.
Cost of working	3·22s. ...	6·13s. per train mile.
Weight of train (50 pass.)	13 tons ...	26 tons.
Passengers per season ...	32,000 ...	37,000.

It is seen that these two lines, both of which are situated close to the Lake of Geneva—viz., in the same district—are worked under very similar conditions, and thac the electrical working represents a saving of about 50 per cent. as compared with steam. This saving, as I stated in my paper, applies not only to rack railways and cable traction, but equally to ordinary steep-grade, as well as to flat lines worked by electricity.

Dr. Preller.

At Barmen, the ladder rack had to be used, because part of the line is laid in a public road. The differentiated Abt rack, used on the Salève, obviates the slight hammering of the pinion teeth incidental to the ladder rack; but the motors, being spring-suspended, are not appreciably affected by the difference of rack.

The further point raised by Mr. Lea respecting the electrical working of rack railways crossing mountain ranges (*e.g.*, the Brunig Pass railway, in Switzerland) relates, not so much to local lines now under discussion, as to the wider question of the working of trunk railways with heavy electrical locomotives, which question I reserved for separate and subsequent treatment.

With reference to the total efficiencies on the electric cable, and on the rack and adhesion lines mentioned in the paper, the average losses are as follows:—

	Electric Cable.	Rack and Adhesion.
Between turbine shaft (or engine) and dynamo ...	5 per cent.	5 per cent.
In dynamo	10 "	10 "
In transmission	5 "	5 "
In motors and gearing (and cable)	25 "	20 "
	45 "	40 "

Hence the total efficiency works out—

For cable railways ... $0{\cdot}95 \times 0{\cdot}90 \times 0{\cdot}95 \times 0{\cdot}75 = 60{\cdot}9$ per cent.

For rack and adhesion railways ... $0{\cdot}95 \times 0{\cdot}90 \times 0{\cdot}95 \times 0{\cdot}80 = 64{\cdot}9$ "

2. With reference to the trolley wheel exhibited by Mr. Holroyd Smith, it appears to me that the extra groove, so far from removing, would aggravate the disadvantages inherent to the trolley wheel with fixed spindle, more especially in curves, where the rasping and scraping of the wheel against the contact wire is detrimental to both. As already mentioned in my paper, a sliding contact, such as Messrs. Siemens & Halske's,* obviates

* Messrs. Siemens & Halske's sliding contact is used on the Buda-Pesth suburban lines, at Dresden, Hanover, Barmen, Genoa, Muhlhouse, and is in course of being extensively applied on several other lines. Messrs. Siemens Bros., Ltd., have also applied it in a modified form at Hobart Town.

Dr. Preller. many of the defects to which the trolley system is liable. On the other hand, I fully agree with Mr. Holroyd Smith that, for the thoroughfares of European cities, the Buda-Pesth lateral slot is a better, because simpler, conduit system than the central slot, which is more liable to interfere with the ordinary vehicular traffic.

3. As regards the rule advocated by Mr. Wilkinson, and also by Mr. Parshall, that the sectional area of the copper bonding at the rail joints should be equal to one-sixth or one-seventh of that of the rail, so as to ensure equal conductivity, the following case, tested by myself, will show that, in European practice, such heavy copper bonding is not necessary, provided the joints of the permanent way as return circuit be *per se* of a substantial character. On the Salève line, where the permanent way consists of flange steel rails with metallic cross sleepers, the fish-plates and fastenings have a sectional area of 1,900 sq. mm. (3 sq. in.), equal to that of the rail. No copper bonding was used when first the line was opened, but, owing to the serious telephonic and telegraphic disturbances resulting from that omission, the company was enjoined to apply a remedy forthwith. The copper bonding adopted consists of a short stranded cable of seven 3-mm. wires at each joint, the sectional area being 63·5 mm. square (0·1 sq. in.), equal to 445 sq. mm. of steel, or only 20 per cent. of the rail section; whereas, assuming the fish-plates to be non-conductive or non-existing, the sectional area of the electrical bonding should have been $\frac{1,900}{7} = 275$ sq. mm. (0·42 sq. in.), or more than four times heavier. The fact that since this bonding no further disturbances have been recorded, confirms what I stated in my paper—that a substantial permanent way in itself provides 80 per cent. of the requisite conductivity, and that hence this percentage can be saved in copper bonding. As a very simple and efficient electrical bonding I may mention a copper fish-plate, soldered and bolted either to the web or to the bottom of the flange of the rails at the joint, as used respectively on the Salève conductor rail and at Murren.

4. With respect to Mr. Wilkinson's diagram of a load curve on one of the American tramways, he stated himself that, the

readings only being taken at intervals of half an hour, the diagram was not reliable. That diagram would approximately represent the load curve of a lighting or of a power installation for industrial purposes; but as an example of a traction load curve it is, for practical purposes, absolutely fallacious and misleading. The only reliable load curve is that drawn by a self-registering ampere-meter, such as is, *e.g.*, used at the power station of the Marseilles line. M. Dubs, the resident electrician and technical manager of that interesting line, of which I gave a full account in *Engineering*, 1893, has kindly sent me, at my request, the following original self-registered diagram of an average working day (29th November last) of 12 hours, with 15 cars simultaneously on the line. The rapid fluctuations of load, often from zero to a maximum of 350 to 400 amperes, and *vice versâ*, in the space of one minute, show the essential difference, not only between a traction and a lighting load curve, but between an automatically registered diagram and one plotted from half-hourly (or even 10-minute) readings, as shown by Mr. Wilkinson. Dr. Preller.

5. As regards the opinion expressed by Mr. Parshall that there is little prospect of alternating-current motors being used for tractive purposes, I can only say that I have very good reason for dissenting from his view. In the meantime, his own company proposes to use three-phase current for transmission on a line at Portland, Oregon; and although it is to be transformed along the line to direct current for the car motors, it is still an application of alternating current, and therefore goes to confirm the proposition I advanced in my paper that, more especially for longer electrical lines than have hitherto been constructed, alternating will probably before long supplant continuous current.

6. With reference to Mr. Robinson's remark that the question of direct driving of generator dynamos, to which I referred in the paper, should have been discussed, not now, but three years ago, I may say that a discussion on this subject took place as recently as last spring at the Institution of Civil Engineers, in connection with the Liverpool Overhead Railway; that Captain Sankey himself took part in it; and that the question will

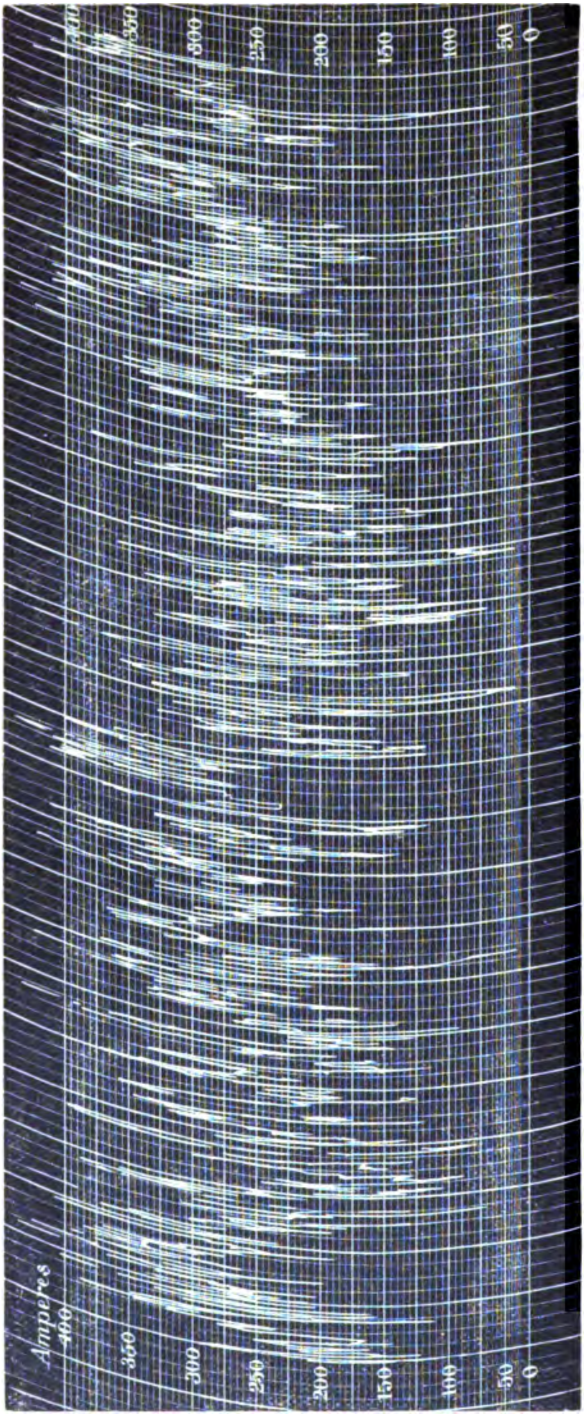


Diagram of Load Curve, Marseilles and St. Louis Electric Road. 29th November, 1894, 5 a.m. to 6 p.m. 12 hours. 15 cars.

probably continue to be discussed for a long time to come. As Dr. Preller. the best proof of the accuracy of my contention that for *tractive* purposes indirect driving by one large low-speed engine is in certain, though by no means in all, cases preferable to direct driving by a group of small high-speed engines, I will now give the particulars of the Marseilles case, mentioned in my paper. These particulars have been kindly supplied to me by M. Dubs, and the following comparison is an abstract thereof:—

	Direct High-Speed Driving.		Indirect Low-Speed Driving.
	3 Compound Double Vertical Acting Engines, 100 H.P. each, 260 revs.; and 3 Bipolar Dynamos, 500 revs.		1 Corliss Engine, 300 H.P., 80 revs., Rope Driving; and 1 Multipolar Dynamo, 300 revs.
Consumption of fuel per car mile ...	13·8 lbs.	... ...	7·22 lbs.
" " " per effect. H.P.	6·95 "	... ...	3·67 "
" " steam " "	35·2 "	with condensation	22·00 "
" " " " "	48·11 "	without "	33·00 "
Total traction and maintenance expenses per car mile	4 2 pence	... ...	3·3 pence.

These figures speak for themselves, and show the considerable saving which has resulted from Corliss (Van der Kherkowe) engines being substituted for the small high-speed vertical (Œrlikon) engines. The uneconomical working of the latter is, to some extent, due to their defective system of regulation; but the comparison, nevertheless, shows the superiority of the larger unit over a number of smaller high-speed units, which is still a conspicuous feature in many lighting installations in this country.

The Corliss type of engine is admirably adapted for lines with rising and falling grades and an *intermittent* traffic of two cars per mile (or four cars per mile of double line), involving great fluctuations of load, as is the case at Marseilles; whilst for flat lines, with a regular traffic of three and more cars per mile, direct driving by large high-speed units is more suitable. Moreover, the reservation I made in the paper as regards certain exceptions to the rule of direct driving for *tractive* purposes is amply justified by experience, as is shown by the great majority of European lines opened for traffic within the last three years, on which indirect driving is used—to wit, the City and South

Dr. Preller. London, Liverpool Overhead, Guernsey, and Isle of Man lines in the British Isles, and the 30 to 40 Continental lines made by such companies as the Berlin Allgemeine Elect. Gesellschaft, the French and German (Union) Thomson-Houston Companies, Messrs. Siemens & Halske, and others. I understand that even in the two new traction installations now in course of erection in this country by the Thomson-Houston Company, indirect driving will be used. I can therefore only emphasise what I stated in my paper—that, although direct driving should always be aimed at as a desideratum, there are cases, such as those specified, in which, for *tractive* purposes, indirect driving, either by steam engines or turbines, is preferable.

On the other hand, I quite agree with Captain Sankey that direct driving does not entail damage to the generator engine in case of short-circuit. I have myself witnessed the destructive effects of most violent atmospheric discharges on the armatures of large dynamos mounted direct on turbine shafts, when the turbine was arrested by the shock, but in no way damaged.

7. As regards the further view expressed by Mr. Robinson that the subject of steep grades does not touch us very closely in this country, I may point out that that contention is an absolute fallacy, and ignores the physical geography of the British Isles. The whole country from the South Coast to the Scottish Highlands may be said to abound in steep-grade roads such as, *e.g.*, those of the northern suburbs of the metropolis; and notably in the manufacturing districts and in Scotland grades of from 5 to 8 per cent. are met with almost in every town, and at every turn in the country. Such grades can be economically overcome and worked only by electrical traction, and it is on this account that Continental lines such as those of Florence, Zurich, Marseilles, and others with similar grades, afford highly instructive precedents, in view of the construction of light railways and road railways in this country.

With regard to such lines in sparsely populated agricultural districts, no more instructive and typical example so far exists than the electric metre-gauge road railway from the Lake of Lucerne to the village of Stans, of which I shall

shortly give a full account in *Engineering*. This overhead trolley line, three miles long, is laid on one side of the public road, 20 feet in width, so that the rolling stock, 6·5 feet in width, leaves 13·5 feet free for the ordinary vehicular traffic. There are 10 to 12 trains (each composed of one motor car and trailer) each way per day; the resident population of only 3,000 inhabitants uses the line at the astonishing rate of 25 passengers per head of population per annum; and the net receipts yield a return of 4 per cent. on the capital of £4,500 per mile. There is no reason why there should not be a large opening for lines of that kind in the agricultural, manufacturing, and suburban districts of this country. With proper legislative facilities and economical management, a return of 4 per cent. on a capital of £6,000 per mile might be obtained, provided that the success of such lines be not vitiated by excessive preliminary expenses and financial charges, excessive fees and salaries, and local prejudice. Dr. Preller.

In conclusion, I have to thank the meeting for the kind reception accorded to my paper.

In reply to correspondence.

8. With regard to Mr. Alfred Dickinson's remarks, I am glad to see that his estimate of the cost of lines on the conduit system in this country agrees with the one I have given in my paper. Mr. Wilkinson's figures, if they include permanent way, installation, and equipment, are much too low; and the same applies to General Webber's estimate of £2,000 per mile as the cost of lines in country, more especially agricultural, districts. Having regard to the higher cost of labour in this country as compared with the majority of Continental countries, the cost of electric lines adequately equipped cannot be put at less than—

Conduit system	£10,000	per mile of single line	in towns.
Overhead „	£8,000	„ „ „	in towns and suburbs.
„ „	£6,000	„ „ „	in country districts.

The last-named figure applies to the narrow or metre (3·3 ft.) gauge laid on one side of the public roads. The 4 ft. 8½ in.

Dr. Preller. gauge, which for country lines exceeding six miles in length may be said to be pure waste of space and money, would, in the majority of cases, involve widening of the existing roads, and therefore additional expenditure. I may add, with reference to General Webber's estimate of only two or three trains each way per day on a light electric railway, that such a service could never pay, even with the aid of storage batteries; but that the great advantage of electrical traction consists precisely in the much more frequent train service with motor cars and trailers, as evidenced by the Stans line.

9. In reply to Mr. Lundberg's question relating to the electric safety brakes to which I referred in my paper, the motor cars or locomotives, in addition to the ordinary mechanical brake, are generally fitted with two appliances—one for reversing the current; and another, by means of a special switch, for utilising the energy developed by the (series-coupled) motors, as brake power on the descent when the car or locomotive is out of circuit, viz., derives no current from the contact wire, and acts independently as dynamo, the vehicle being, in other terms, simply held by the magnetic field.

10. In answer to Mr. Geipel's question relating to the difficulty of regulating low-pressure turbines, I may say that such turbines, more especially with very variable volume and head of water, as is probably the case at Worcester, have hitherto nearly always required additional regulation by hand, so as to keep the tension, as registered by the voltmeter, as constant as possible; but that a very sensitive automatic system of mechanical regulation of low-pressure turbines has recently been introduced at the new lighting (alternating current) installation of Interlaken, Switzerland, of which I shall before long give a full account in *Engineering*. As an electrical means of compensating the variations of low-pressure turbines in connection with separate exciters (high-pressure turbine and dynamo), I may refer to the automatic Thury regulator, described in *Engineering*, April 6th, 1894, in my paper on the Salève Electric Rack Railway.

In reply to Mr. Geipel's further remark that, in advocating

alternating current for electrical traction, I had omitted the important advantage of the commutator being thereby dispensed with, suffice it to say that I did not dwell on that point because it follows *ipso facto*. Moreover, the principal saving on lines exceeding, say, eight miles in length, will be not so much in motors as in generators and transmission, more especially if single-phase alternating current is used. Dr. Preller.

The PRESIDENT: At this late hour I will only ask you to give a hearty vote of thanks to Messrs. Wilkinson, Blackwell, and Dawson, and Dr. Du Riche Preller, for their very interesting papers, which have given rise to such an instructive discussion.

The vote was unanimously accorded.

The PRESIDENT: With regard to the balloting list of Council and Officers, I have much pleasure in informing you that the scrutineers report the result of the ballot for Council and Officers for the year 1895 to be as follows:—

President:

R. E. CROMPTON, M. Inst. C.E.

Vice-Presidents:

Sir DAVID SALOMONS, BART., M.A.

Sir HENRY MANCE, C.I.E., M. Inst. C.E.

Professor GEORGE FORBES, F.R.SS. (L. & E.).

ROBERT KAYE GRAY, M. Inst. C.E.

Ordinary Members of Council:

Major A. H. BAGNOLD, R.E.

FRANK BAILEY.

G. VON CHAUVIN.

W. B. ESSON, M. Inst. C.E.

S. Z. DE FERRANTI.

WALTER T. GOOLDEN, M.A.

Professor A. B. W. KENNEDY, LL.D., F.R.S., M. Inst. C.E.

WILLIAM E. LANGDON.

Professor JOHN PERRY, D.Sc., F.R.S.

AUGUSTUS STROH.

JAMES SWINBURNE.

Professor S. P. THOMPSON, D.Sc., F.R.S.

Associate Members of Council:

AUGUSTUS CALDER. | Captain GEORGE CARR, R.E.
J. M. V. MONEY-KENT.

Honorary Treasurer:

Sir DAVID SALOMONS, Bart., M A., Vice-President.

Honorary Auditors:

FREDERICK C. DANVERS, India Office, S.W. | AUGUSTUS STROH.

Honorary Solicitors:

Messrs. WILSON, BRISTOWS, & CARPMAEL, 1, Copthall Buildings, E.C.

I also have to report that the following candidates have been duly elected:—

Member:

Thomas Barton.

Associate:

F. C. Dixon.

Students:

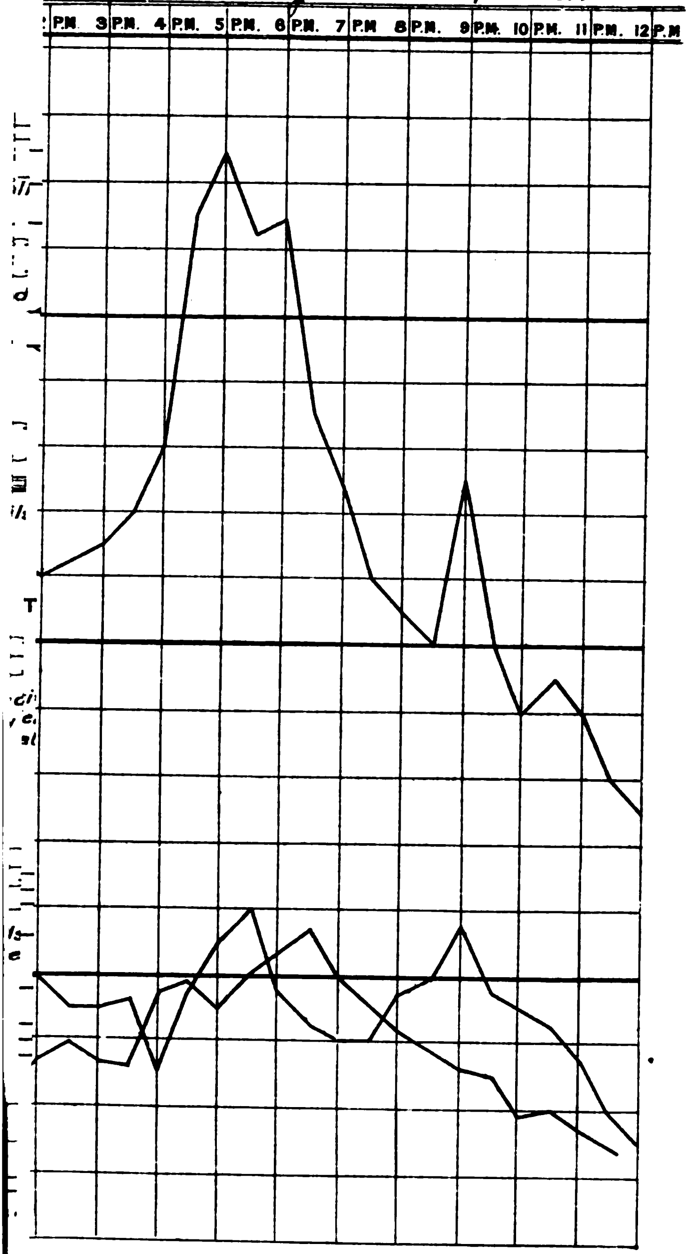
Stanley Beeton.
Henry William Kennedy Irvine.
Henry Herbert Stanley Marsh.
Roland Sydney Robertson.
Arthur Holroyd Sears.
Richard Norman Vyvyan.

The meeting then adjourned.

ELECTRIC DEPARTMENT

Plate B.

RVE — Friday November 24 1894

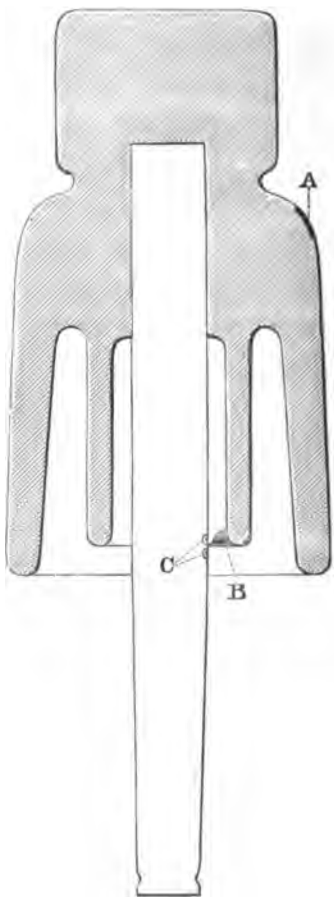


n of Weather, ____ Snow,

COMMUNICATION.

CALCUTTA, *November* 19*th*, 1894.

DEAR SIR,—The following case of lightning happened on the telegraph line between Bombay and Bhusaval in October:—



One of the iron wires was broken, and the cause put down to lightning. As no insulators were smashed, the local superintendent, Mr. Kenyon, called for the ends of the wire, and had two of the white porcelain insulators on each side of the break removed for examination. Of the four insulators, one was cracked and the stalk loose. The other three appeared to be entirely undamaged, except that each had a little brown mark at the edge of the inner cup, in the position marked B in accompanying sketch; and on each stalk, at C just opposite, was a small mark about the size of a pin's head, with a little conical point in the centre, where the flash had apparently sparked across. There was also a brown mark at A where the wire binder touched the insulator. At each brown mark the glaze of the porcelain was destroyed, being reduced to a powder which disappeared in water. The three apparently undamaged insulators were tested after being immersed in water for 24 hours, and each gave an insulation resistance of over 5,000 megohms.

If the lightning went *through* the porcelain it would assuredly have destroyed the insulation; failing this, it must have passed over the whole surface of the porcelain to get from the line wire to the edge of the inner cup—which seems curious.

Yours truly,

P. V. LUKE,

Director, Construction Branch,
Indian Government Telegraphs.

THE SECRETARY,
Institution of Electrical Engineers.

ABSTRACTS.*

C. KIRN—ON THE RESEMBLANCE BETWEEN THE EMISSION OF LIGHT IN THE AFTER-GLOW OF A GEISSLER TUBE AND THE COMMENCEMENT OF INCANDESCENCE IN SOLID BODIES.

(*Wiedemann's Annalen, Vol.* 52, *No.* 6, *p.* 381.)

According to H. F. Weber, the light emission of heated solids does not begin, as Draper assumed, with dark red light, but with a dark foggy-grey luminosity, which shows itself in the spectroscope as a band, situated in the green-yellow at that point where the brightest spot of the normal spectrum lies, which spreads on both sides with rising temperature. This grey light begins at a much lower temperature than the red, and varies in different bodies. From the researches of Stenger and of Ebert on the limits of sensibility to light, it is seen that the phenomenon is due to the fact that the sensibility of the eye is greatest for this portion of the spectrum. The author observed analogous phenomena in a tube supplied by Geissler, which had a spiral form with seven spherical enlargements On the inner walls of the tube, and especially in the spherical parts, were deposits of colourless crystals, and also single crystals of larger dimensions, being presumably sulphuric anhydride. This tube glows in the dark for more than half a minute after the passage of the electric discharge. The spectroscopic observations by the ordinary Desaga apparatus with one prism had the following result:—During the passage of electric discharges, the tube shows a line spectrum, which is especially clear in the narrow parts of the tube, and the brightest lines in which are apparently coincident with those of nitrogen and carbonic oxide. At the beginning of the discharges the spherical parts show the same spectrum clearly; but as soon as the formation of the peculiar foggy appearance begins in the spheres, the line spectrum becomes less distinct and becomes more nearly continuous, while the background gets brighter. The weak spectrum remaining, due to the after-glow after the discharge ceases, is continuous, without noticeable dark spaces, and occupies at first the whole space of the former line spectrum, but begins fairly soon to contract from both ends, and more from the blue than the red end, until it forms a band lying between the wave-lengths 555–495 $\mu\mu$, which very gradually contracts and disappears. The colour of this band is not

* The Editing Committee regret that a very unintentional injustice was done to Dr. C. S. Du Riche Preller, Member, in the last part (No. 113) of the *Journal*, through the circumstance of an article on the Mont Salève Electric Railway, of which an abstract was given (page 607), being described as an anonymous article from the *Elektrotechnische Zeitschrift*, whereas it was, in fact, little else than a German translation of a series of articles which had been published by Dr. Preller, *under his name*, in *Engineering*. Contrary to the best traditions of journalism, the *Elektrotechnische Zeitschrift*, when thus reproducing the articles, entirely suppressed the name of the author, and only made so obscure an allusion to the source from which it had taken them, that our abstractor failed to notice it.

that of the corresponding part of the spectrum, but is a peculiar faint greyish yellow, which gradually becomes darker as it fades. The position of final extinction corresponds about to the position of the E line in the solar spectrum, and with the brightest part of the ordinary visible spectrum. The whole phenomenon is just the inverse of what is observed at the beginning of the emission of light with glowing solid bodies.

THOMPSON and WALKER—THE WINDING OF ALTERNATE-CURRENT ELECTRO-MAGNETS.

(Philosophical Magazine, Vol. 37, No. 229, p. 564.)

The following formulæ from this paper will be of use to designers of magnetic relays, &c., for use with alternating currents.

To find the ratio of the volts required for a given electro-magnet to produce the same ampere-turns with direct and alternating currents:

Let V_a be the alternating volts and V_c the direct volts. Then

$$\frac{V_a}{V_c} = \frac{\sqrt{R^2 + p^2 L^2}}{R};$$

and if, as is generally the case, R is small compared with p L, it is sufficiently near to take

$$\frac{V_a}{V_c} = \frac{p L}{R}$$

(in these formulæ $p = 2 \pi n$, where n = periods per second and L is the coefficient of self-induction), or the alternate voltage ratio is proportional to the frequency and to the time constant of the electro-magnet. For this ratio we may on certain assumptions find an expression in terms of the dimensions of core and coil for a closed magnetic circuit; but the assumptions involve uncertainties of as much as 50 per cent.

Secondly, a very simple expression may be found for the number of turns required to obtain any desired induction, N, in the iron. If the iron of area A is subjected to cycles of magnetisation of mean permeation = B, then N = A B; if the frequency = n periods per second, the back E.M.F. = 2π W N/10^8 volts. If the resistance is negligibly small, this equals V, the volts of supply; whence,

$$W = \frac{V \times 10^8}{p N}.$$

C. RICHTER—ON THE BENARDOS SYSTEM OF ELECTRIC WELDING.

(Elektrotechnische Zeitschrift, 1894, No. 30, p. 415.)

The Benardos system is more suitable in some ways for the welding of two pieces of metal than the Thomson method. It is well known, for instance, that the latter requires an immense amount of energy to be spent in producing sufficient

heat at the surfaces of the metal to effect the required weld; and the author of this article begins by pointing to some of the disadvantages which have hitherto retarded the introduction as a practical process of the Benardos system. The first and most important defect is the hardening of the iron in the immediate neighbourhood of the arc, the effect of the preceding mechanical and other processes being thus to some extent reversed; and it is difficult, if not impossible, to restore the quality thus lost. The iron also suffers as regards tensile strength and elongation, a mean of 20 rods about 210 sq. mm. in area giving a tensile strength of 28·4 kilos per sq. mm., with an elongation of 2 per cent.

The hardening is chiefly due to the quick cooling, due to the large masses of metal in contact with the welding place, which cool it more quickly than plunging in water. The author has not found the opinion confirmed that the hardening is due to absorption of carbon from the arc into the iron, and has found that the softness can be restored by reheating and slow cooling; but the latter operation has no effect upon the tensile strength, the mean breaking strain of 19 rods being 24·3 kilos. per sq. mm., with a mean elongation of 2·6 per cent. after annealing.

The process may be used for other metals than iron where the above defects are either of less importance or even entirely absent, as, for example, copper and certain of its alloys, lead, tin, and gold and silver.

A second obstacle to its general introduction is the relatively high cost of an accumulator battery. It must be noted that the battery only works intermittently, perhaps 100 hours per month, and the losses by overcharging the cells in the intervals, and so on, amount to a considerable sum. The author has therefore tried to avoid the use of accumulators by modification of Benardos' arrangement. The latter, as is well known, consists of a dynamo, D, coupled to the battery, A, and the work, S, in parallel. The battery is divided into groups of 5–10 cells of suitable output. The poles of each group are connected to a suitable switch or plug box. The arc is started by touching the work, which forms one pole, with the carbon forming the other pole of the arc, thus short-circuiting dynamo and cells for a moment; and when the arc breaks the dynamo charges the cells.

The same advantages are gained if a suitable resistance be substituted for the cells, and the dynamo be of about double the output: the loss in the resistance can be made less than that in the batteries; and in the intervals the dynamo can run light. The excessive current at starting can be avoided by having an inductive resistance in circuit, and jars are prevented by running with slack belt; but in any case these disadvantages are shared with the original Benardos arrangement. An automatic switch can cut out the main resistance while the work is on. Where more than one job is going on at the same time, they may be arranged to keep the dynamo always running on useful work.

The third and last cause of the slow progress of the electric method of welding is the bad effect of the intense light and the gases evolved on the worker. The combination of coloured glasses used as a protection is powerless to prevent inflammation, although the eye gradually gets inured to it in most cases. The glasses make it difficult to see the work properly. The author recommends the use of a sort of mask covering the upper part of the face, and provided with spring arrangements for working the glasses.

J. ELSTER and H. GEITEL—FURTHER EXPERIMENTS ON LIGHT AND ELECTRICITY.

(*Wiedemann's Annalen, Vol.* 52, *No.* 7, *p.* 433.)

The three alkali metals, sodium, potassium, and rubidium, have different electrical sensibilities with regard to coloured light. Potassium reacts in a remarkable manner on blue light, but has little effect on light rays of greater wave-length; sodium acts from the blue into the yellow, and then drops off suddenly; while rubidium reacts with only one-quarter the effect on blue that it has on yellow, and is twice as sens tive to red as to blue. The authors reached this conclusion in the following manner:—A glass sphere was taken and filled with an atmosphere of rarefied hydrogen. In th's a thin sheet of the metal under observation was used as negative, and a platinum wire as positive electrode of a high-pressure battery, and by means of a very delicate galvanometer the amount of current passing under various conditions of illumination of the negative electrode was measured. The sensibility to different colours was measured by the deflection of the galvanometer. In the case of illumination by polarised light, the current is greatest when the plane of polarisation is perpendicular to that of the metal sheet, and least when the planes coincide.

Further experiments by the authors are described on the effects of light on electric oscillations, and on the production of negative electricity on the surface of freshly broken fluor-spar when illuminated by daylight or sunshine. The latter effect is dependent on the kind of spar, and the blue-violet and greenish varieties are the most sensitive to light.

F. KOHLRAUSCH and A. HEYDWEILLER—ON PURE WATER.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 26, *p.* 359)

Eighteen years ago F. Kohlrausch succeeded in producing, by distillation *in vacuo*, water which at 18° had a conductivity of $0{\cdot}25 \times 10^{-10}$, mercury being taken as unity. By the use of one of the same distilling apparatus, the authors have succeeded in producing water of the following conductivity:—

At 0°.	18°.	25°.	35°.	50°.
0·014	0·040	0·058	0·089	$0{\cdot}179 \times 10^{-10}$

1 mm. of this water has at 0° a resistance equal to that of 40 million kilometres of copper wire of the same section, about a thousand times the earth's circumference, and it is probably the purest water that ever existed. The water was found to obey Ohm's law, having the same resistance with 4 as with 100 volts pressure.

When in contact with air the conductivity rises very quickly; it also rises when the current remains on some time, returning to its original value gradually after the current is stopped. The temperature coefficient varies in such a manner as to lead one to suppose that the value $0{\cdot}04 \times 10^{-10}$ at 18° is very nearly the limit, and theoretical considerations lead one to suppose that $0{\cdot}036 \times 10^{-10}$ must be near the value of the conductivity of *absolutely pure* water at 18°.

G. RÖSSLER and W. WEDDING—ON THE PRESSURE AND CURRENT CURVES OF VARIOUS TYPES OF ALTERNATOR, AND THEIR INFLUENCE ON THE ILLUMINATING POWER OF THE ELECTRIC ARC.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 23, *p.* 315.)

The authors used in their experiment three alternators, by Ganz, Wechsler, and Siemens respectively, whose pressure curves were of very different types. The Ganz machine has a curve which in the half-period rises suddenly to a very high value, falls equally suddenly, and remains for about half the time at a very low value. The lamp has to receive its energy in a sudden jump, lasting about one-third of the whole period. The Siemens machine behaves in a directly opposite manner, the electrical energy rising very slowly to a maximum, at which it remains for a considerable time, falling slightly, then rising to a second higher maximum, and falling rapidly immediately after. The current-curve is especially flat, the slight peak being chiefly in the volts, and the current through the lamp is as nearly constant as possible. The Wechsler machine lies between the two, and is very nearly a sine curve.

Extensive series of observations of the illuminating power of the arc with these alternators were made, and curves and tables are given in detail; and it was found that the lamp was 44 per cent. more efficient with the Wechsler than with the Ganz machine. The Siemens machine could not be tried at the same frequency (80 ∿), but at 120 ∿ its light emission was 6 per cent. higher than the Wechsler machine. The Wechsler machine is better in another respect, making the lamp burn more silently than the other two; and but for this the flat-topped curve is found to be best.

Experiments with direct currents showed that the direct-current arc is far more efficient, partly because the reflector used with the lamp has not to reflect so large a proportion of the light.

F. HIMSTEDT-ON EXPERIMENTS WITH TESLA CURRENTS.

(*Wiedemann's Annalen*, *Vol.* 52, *No.* 7, *p.* 473.)

The author has succeeded in reproducing most of Tesla's experiments with very simple apparatus: he utilised at first the Lecher method of producing electrical oscillation, but later on used the still more common Leyden jar. The pole of a powerful Ruhmkorff coil 50 cm. long and 20 cm. in diameter, and used with five or six accumulator cells, was connected to the inner coatings of two medium-sized Leyden jars insulated from one another by standing on paraffin blocks, and also to a spark micrometer. The outer coatings of the jars were connected together by a copper wire 4 mm. thick and 120 cm. long, bent into U shape. A 16-volt glow lamp put in parallel with this wire was soon brought to incandescence when the spark micrometer was suitably adjusted. When jars 16 cm. in diameter and 42 cm. high were used, as many as three lamps could be made to glow—a 65-volt lamp below, a 16-volt lamp in the middle, and a 2-volt lamp at the top. If the nipple of such a lamp be filed off it ceases almost entirely to glow. Tesla ascribes this fact to the alteration in the molecular bombardment in the lamp; but the author considers that it is due to the convection of heat by the air admitted.

If the incandescent body be a platinum wire of 0·05 to 0·1 mm. diameter, it oscillates violently while glowing, not in one plane like a string under tension, but in every possible plane, becoming a model of a beam of natural light. It is essential to the success of this experiment to use a proper interruptor and a suitable spark micrometer. As interruptor the author used the Foucault form, with tough zinc amalgam in the place of mercury, and covered with machine oil. The balls of the micrometer are best made of zinc.

The Tesla transformer was made as follows:—A glass tube of 4 cm. diameter was taken, and on it were wound 10 turns, 1 cm. apart, of a wire 4 mm. thick. Over this was pushed an ebonite tube, 6 mm. thick, on which were 200 turns of wire 1 mm. thick and spaced with 1 mm. between each. The whole transformer was placed in an earthenware container filled with machine oil, the secondary terminals being two metal balls on ebonite pillars. The primary was put in the place of the U-shaped wire, between the outsides of the Leyden jars. When the interruptor begins working, brush discharges start from these balls, and sparks spring to a conductor put near. Two parallel wires starting from the balls have between them a broad band of light 3–4 metres long. If one pole be put to earth, and to the other be connected a wire 15–20 cm. long, hanging freely downwards, it begins to move when the interruptor is started, and describes the surface of a cone, which is easily seen in a dark room by the brush discharge, which renders it luminous

If anyone takes hold of the pole of such a transformer with the hand, rays of light start from any part of his body when a conductor is held near. If he stands on a metal plate he feels a pricking sensation in his feet, and in the dark the rays coming out of the soles of his shoes may easily be seen. If several persons form a chain, and the first touches one pole of the transformer, while the last holds in his hand a vacuum tube with or without electrodes, the tube glows brilliantly. None of the persons feel any symptom of the electrical phenomena.

If one pole of the transformer be earthed and the other connected to a metal sphere 60 cm. in diameter, vacuum tubes glow brightly up to 15 feet away. A glow lamp connected to the unearthed pole glows faintly in a phosphorescent manner; but if a large metal reflector be placed over the lamp it glows brilliantly, while the filament oscillates so violently that it soon breaks. If a conductor be held near the point of the lamp, the glass is immediately punctured by the current, a continuous and brilliant stream of sparks passes through the opening, and the filament glows until it burns away.

In the second portion of the article the author remarks that a Tesla transformer differs in important particulars from an ordinary Ruhmkorff coil. A vacuum tube connected in any manner to the transformer shows kathode light at both electrodes, and evenly distributed anode light in the centre. An alteration of direction of the primary current, or alteration of pole, has no effect in altering this phenomenon. An electroscope is always charged positively if held to either pole, and both poles give positive Lichtenberg figures only. It was found that this effect depended on the nature of the surrounding medium. Air and oxygen produce positive discharge; hydrogen, illuminating gas, nitrogen, carbon dioxide, and ammonia give negative discharges. If a pole have two points immersed in air

and hydrogen respectively, positive and negative discharges take place simultaneously, according to the medium. If a pole be in oxygen, and nitrogen be gradually added, an electroscope shows first a positive charge, first increasing, reaching a maximum at the mixture corresponding to air, and then diminishing, and ultimately becoming negative. With a Ruhmkorff coil the charge in the electroscope changes sign if the primary current be reversed.

A. HEYDWEILLER—THE VILLARI CRITICAL POINT IN NICKEL.

(*Wiedemann's Annalen, Vol.* 52, *No.* 7, *p.* 462.)

The author points out that hitherto researches on the point have indicated a difference in the relation of magnetic to elastic qualities for the metals iron and nickel. The researches of Wiedemann, Nagaoka, and Zehnder have shown the effects of torsion on longitudinal and circular magnetisation; and the effects of pull on longitudinal magnetisation have also been investigated. The two phenomena are connected in this way—that the torsion produces an expansion in one direction, and a compression in the direction at right angles to it; and the chief difference between iron and nickel lies in this—that the former with low magnetisation gets an increased induction when stretched and a diminished induction when compressed in the direction of the magnetising force. The effect reverses with increased forces, so that there is a point at which a certain force, depending for its value on the magnetisation, produces no alteration of induction. Villari was the first to observe the increase of induction by a tensile strain; and the point at which with increasing stress the induction attains its original value, before beginning to diminish, is called, after him, the Villari critical point.

No such point has hitherto been observed in nickel; the application of a tensile force diminishing, while compression increases, the value of the magnetisation for given magnetising force. On the other hand, the effects observed in iron are in accordance with what would be expected on the Ewing-Weber theory of molecular magnets; and it was therefore advisable to more carefully investigate the subject of the apparent difference between iron and nickel, which appeared to be qualitative. It must be observed that the reversal of the effects of tensile stress on the temporary magnetism of nickel with strong magnetisation, described by Tomlinson in 1890, is not the Villari curve, but relates to quite another effect.

It seemed probable that the reversal should be looked for with very weak forces in nickel, and the apparatus was prepared accordingly, a magnetometric method with astatic needle system being used, with the vertical nickel wire 4·7 cm. away. The lower end of the wire—about on a level with the upper magnet needle—was inside the magnetising coil about 7 cm. from the end, and thus in a very uniform field. It was easy to arrange the height so as to produce the maximum deflection. The tension and compression were produced by a lever above, with sliding weight: the wire being prevented from moving sideways by confinement in a glass tube. The forces of compression went up to 2·7 kilos., and the tensile forces to 3·9 kilos. The magnetising forces may be taken as purely longitudinal, the horizontal component of the earth's field not having a sensible effect. The usual reduction to C.G.S. units gave 40 millimetres deflection with a scale 1,860 mm. away for one C.G.S. unit of induction. One difficulty

lies in the demagnetisation of the nickel, which is very difficult to effect: the gradually decreasing alternate current is not sufficiently sensitive; and even the very repetition of the experiment suffices to give the nickel a permanent set. The author appears to have attained his end by vibration, and very weak demagnetising forces. The nickel wire was made by Desaga, of Heidelberg, chemically pure, 0·15 cm. thick and 46 cm. long, well annealed. It has a specific conductivity of 7·7 times that of mercury (both at 0°), being that given by Feussner, but smaller than those of Matthiessen and Vogt and Dewar and Fleming. Six tables of figures embodying the results are given in the paper, with values of I varying between about 0 and 10 C.G.S. units, and with positive and negative mechanical stress. The results are broadly as follows:—With weak induction the curve representing the relation of the longitudinal intensity of magnetisation, I, to the value of a tensile or compressing force in the same direction, P, shows a minimum and a maximum. Beginning with the greatest negative force, and gradually altering through zero to a maximum positive force, the induction falls steadily, reaches a minimum, rises to a maximum, and then begins falling again. These maxima and minima get less defined and nearer together the stronger the magnetisation becomes, and at a certain value of the latter they disappear entirely. The position of the point where the curve crosses the zero of mechanical stress depends on the previous magnetic and mechanical history of the specimen, and the curve is not often symmetrically divided by this zero of abscissæ. These effects are probably connected with the hysteresis observed in mechanical deformations which are inseparable from the application of the mechanical forces. By continued application of tensile stress the zero may get shifted very considerably, and is only brought back by application of negative forces or pressure. The nickel shows hysteresis in regard to the effects of tension, thus differing from its behaviour when strongly magnetised. Comparing these with the results of Villari, Thomson, and Ewing, it is seen that there is only a quantitative difference in the behaviour of iron and nickel, due to the difference in strength of the molecular magnets.

P. LEBEDEW—ON THE MECHANICAL EFFECTS OF WAVES ON STILL RESONATORS: I.—ELECTRICAL WAVES.

(*Wiedemann's Annalen, Vol.* 52, *No.* 8, *p.* 621.)

The author proposes to investigate on a uniform plan the mechanical forces of attraction and repulsion which each of the different wave-motions produces on a body swinging with it. Only the simplest case is to be considered, viz., when a series of waves impinges on a fixed resonator which does not sensibly react on the source of the waves. On the other hand, the question of the dependence of sign and magnitude of the forces on the resonance will be the subject of the greatest attention. This first section of the research deals with electro-magnetic waves, and the arrangement of apparatus was as follows:—A Hertz primary conductor excites a certain metal body tuned to vibrate with it, the vibrator, which keeps up the oscillations for a considerable period, and therefore serves with advantage as a source of waves of unalterable period; a very light resonator, whose period can be determined in the usual way by measurement of wave-lengths, is hung on a

torsional suspension in the vicinity of the vibrator in such a manner that the oscillations of the latter excite the resonator, and the mechanical forces turn it at the same time, the angle of deflection serving as a measurement of the force acting upon it.

In the experiments the resonator was altered step by step, and each time its period and the corresponding mechanical force acting on it; the observations give directly, therefore, the ratio of mechanical force to resonance. In order to separate the effects of the magnetic and electric components of the electromagnetic oscillation, a vibrator and resonator of the type known as magnetic, as well as a pair of electric ones, were prepared. The magnetic vibrator consisted of a band of zinc bent up, 20 cm. broad and 65 cm. long; and the magnetic resonator was four vertical turns of a fine silver wire whose ends were connected to two horizontal condenser plates whose distance apart was capable of adjustment. The electric vibrator was constructed of two rectangular zinc plates put parallel to one another and joined by a band of copper; and the electric resonator was formed of two cylinder quadrants of aluminium sheet put with their concave sides facing one another, connected by a coil containing self-induction to horizontal turns of wire. The magnetic and electric resonators behaved in a precisely similar manner during the experiments, and the final conclusion from experiment and calculation is as follows:—The mechanical effect of the exciting wave on the resonator is directly proportional to the quantity of energy falling on it, and depends only on the ratio of the number of waves, not on their absolute value. When the resonator is tuned higher than the source of the waves it is attracted; this attraction reaches a maximum when the two are in tune, and then changes rapidly, but stably, into a maximum repulsion as the resonant point is passed, this repulsion becoming less as the two become more out of tune; and the phenomenon is symmetrical as regards the resonant number of oscillations.

R. HAAS—THE SPECIFIC CONDUCTIVITY AND THE TEMPERATURE COEFFICIENT OF THE COPPER-ZINC ALLOYS.

(*Wiedemann's Annalen*, *Vol.* 52, *No.* 8, *p.* 673.)

Since the specific conductivity and the temperature coefficient of alloys are very sensitive, even to minute changes in their constitution, the author considers that both of these properties form good means of settling the question whether copper and zinc at any particular percentages of mixture form a chemical combination or not. In constructing such alloys of from 0 to 100 per cent. zinc, the author could only make those up to 50 per cent. in the form of wire, owing to the hardness and brittleness of the alloys containing higher percentages of zinc; and great precautions were taken to ensure the same initial conditions as regards all the wires used. The differences observed, and probably ascribable to structural difference, amount to about half per cent. The Wheatstone-Kirchhoff bridge was used for the measurements. The results of the observations are given in the following table. It must be noted that in all the alloys the resistance is a linear function of the temperature; they behave like pure metals (excepting iron) in this respect. The table shows that copper alloyed with an increasing amount of zinc increases in resistance, at first rapidly, then more slowly till 34 per cent., where the resistance attains a maximum,

and falls equally quickly from 34 per cent. to 48 per cent. zinc. Between this and pure zinc the curve must turn up again, as the specific resistance is higher for the latter. The maximum at 34 per cent. was not observed by G. Wiedemann, nor by Matthiessen and Vogt.

The temperature coefficient, on the other hand, increases at first rapidly, but with decreasing rapidity as more and more zinc is added, reaching a minimum value between 17 and 30 per cent., where it is fairly constant, and then rises again sharply to within 20 per cent. of its original value at an alloy of 47 per cent. of zinc. An interesting point is the high value found for the temperature coefficient of pure copper—0·00432; hitherto 0·004 has been considered high. The author attributes the difference in his and Mathiessen's results to the superior purity of the metals which the former uses, and especially to the absence of carbon.

It will be noted that the maximum conductivity and minimum temperature coefficient coincide in an alloy having a composition of 34 per cent. zinc and 66 per cent. copper. At this value the compound Cu_2Zn would be formed, if at all; and the chances of this being an accident are rendered smaller by the fact that Ball and Kaminsky showed that the alloys in the proportion Cu_2Sb and Cu_4Sn gave minima of specific resistance. In all these, as in Cu_2O or Cu_2S, copper shows itself as a monad. It is rendered, therefore, very probable that copper and zinc combine in a stable compound Cu_2Zn; and it is also likely enough that it is to this fact that brass owes the qualities which distinguish it from its component metals.

RESULTS OF THE EXPERIMENTS.

No.	Analysis. % Zinc.	Specific Resistance. Ohms.	Temperature Coefficient.	Specific Conductivity.
1	0	0·01576	0·004316	63·45
2	0	0·01592	0·004328	62·81
3	0·71	0·01833	0·003725	54·56
4	1·56	0·02133	0·003185	46·88
5	3·07	0·02372	0·002913	42·16
6	5·51	0·03010	0·002383	33·22
7	9·08	0·03638	0·002044	27·49
8	18·02	0·04763	0·001691	21·00
9	20·29	0·05064	0·001639	19·75
10	22·71	0·05424	0·001607	18·44
11	28·16	0·05826	0·001581	17·16
12	34·23	0·06302	0·001579	15·87
13	40·28	0·05789	0·002116	17·27
14	42·55	0·05307	0·002376	18·84
15	45·19	0·04712	0·002851	21·22
16	46·85	0·04314	0·003105	23·18
27	99·53	0·05883	0·003847	17·00
28	100·00	0·05683	0·004029	17·60

A. KLEINER—ON THE QUESTION OF THE POSITION OF THE ELECTRICITY IN A CONDENSER.

(*Wiedemann's Annalen*, *Vol.* 52, *No.* 8, *p.* 728.)

Franklin showed many years ago that in a charged condenser the conducting portions may be removed and separately discharged, and that if the condenser be then put together again it is found to be charged. Modern measurements show clearly that the greater portion of the charge is in the dielectric, which is polarised. Reckoning on the analogy between dielectric and magnetic polarisation, it should be possible to split up the dielectric material into thin layers, each of which would itself be charged; and a mica condenser lends itself admirably to this experiment. The condensers experimented on were formed by floating thin mica plates, on whose upper side a circular tinfoil coating was stuck, on mercury. They were charged to 300 volts, and the charge measured by discharging through a sensitive galvanometer. The result of the experiments showed that when the dielectric, after charging, was subdivided, each piece when furnished with coatings gave the same quantity of charge as the undivided condenser, supposing always the losses by conduction to be the same; from which it appears that if the insulation were absolutely perfect a mica dielectric might be split up parallel to its surfaces into as many portions as you please, each of which would have the same charge as the original condenser. The simplest explanation of this is a dielectric polarisation similar to that assumed for magnets.

O. GROTRIAN—ON THE MAGNETISATION OF IRON CYLINDERS.

(*Wiedemann's Annalen*, *Vol.* 52, *No.* 8, *p.* 735.)

As already announced, the author's experiments on hollow iron cylinders have led him to the conclusion that with small magnetising forces only the outer layers of a solid cylinder get magnetised, and this effect is very marked. The present article is written for the purpose of overcoming objections raised by Messrs. du Bois and Ascoli.

If a solid cylinder be magnetised vertically up to a point of moderate saturation, and a card of iron filings be laid on it, nearly all the filings collect into a ring, well defined, and following the outline of the flat end of the cylinder on which it is resting.

If a balance be arranged to measure the pull exercised by this cylinder on a thin-pointed steel magnet at various points on the flat surface of the cylinder, the force required to pull them apart is the greater the further the point of contact is from the centre, up to within a millimetre or so of the edge.

These two experiments show that the induction near the surface of the cylinder is greater than in the interior.

If powdered iron be introduced into the hollow of a magnetised iron tube, it shows no tendency to arrange itself in any way regularly, nor to adhere strongly to the sides. If a card covered with filings be lowered into the interior, the central particles are not affected below a certain point in the tube, determined by the magnetising force; and the particles lower than these, or near the sides of the tube,

show no movement when the current is turned on. These phenomena clearly show the existence of screening action. If the tube be shortened into a ring or very short cylinder, the action at the centre is strongly marked, the particles shooting into the air in tree form, while the side particles are unaffected; that is to say, the screening here acts only on the sides, and the centre is left exposed. The magnetisation of an iron ring will therefore be of a different character from that of a cylindrical plate of similar dimensions, whose central portions will be markedly magnetised.

These conclusions agree with those of Schulz, who determined in a Lahmeyer machine the induction for various values of magnetising force, magnetising from a separate source. When he gradually removed the central portions of the magnet limbs, he found, even for small degrees of magnetisation, that the induction was proportional to the area. Schulz ascribed this deviation from what should be anticipated from the author's experiments to the fact that the magnets used by him were short in comparison with their diameter, and this agrees with what his later researches have indicated. As a general result, the author states that the portions of a cylinder of iron, not too short in comparison with its length, which is magnetised in the direction of its axis, are differently magnetised at low saturations in such a manner that the magnetisation of the periphery is much larger than that of the axial portions.

LUMMER and KURLBAUM—BOLOMETRIC RESEARCHES ON THE SUBJECT OF A UNIT OF LIGHT.

(*Elektrotechnische Zeitschrift*, 1894, *No.* 35, *p.* 474.)

A technical measure of light should be easily handled, easily set up, and cheap: the accuracy is a matter of more secondary consideration; while the inverse holds with a unit required for physical purposes of all the standards at present used—candles, Hefner lamps, pentane burners, Carcel lamps, and so on,—only the Hefner lamp fulfils the required conditions, and it has for some time been officially standardised by the Reichsanstalt. This very standardisation, however, presupposes the existence of a standard of reference, and in default of this the Reichsanstalt has hitherto used a series of incandescent lamps which had been compared with one another, and in which the current could be kept constant within 1-100th per cent. The illuminating power of each of these was determined by comparison with a number of Hefner lamps set up according to the rule, and now constitutes in itself a standard of reference independent of the original Hefner lamps. The problem of finding a definite physical standard is therefore a very pressing one.

The Violle platinum standard was found to vary with the purity of the platinum; as did also that proposed by Siemens, varying some 10 per cent. The experiments showed, however, that pure platinum would serve excellently if the temperature could be kept constant. The method used by the authors, though somewhat complex, enables standards to be turned out independently, and not differing by 1 per cent. from one another.

The unit of light proposed is that emitted by one square centimetre of platinum at a definite temperature, which is defined by the ratio of two amounts

of radiation. One of these is that proceeding from the platinum, and the other that portion of it which passes through a certain absorbing medium; and the two amounts are measured by the warming of a bolometer. The absorbing medium is defined as a vessel with parallel quartz sides of certain thickness, enclosing a layer of water, also of defined thickness.

In this manner a certain temperature, which need not be defined in centigrade degrees, is kept constant; and it was assumed that the platinum, if kept at a certain fixed temperature, would emit the same amount of light; and the proof of this assumption was experimentally obtained.

The current heating the platinum is varied until the galvanometer deflections with and without the quartz screen show a ratio of 10 : 1, and the light passing through a diaphragm having a hole 1 $cm.^2$ in area is the required unit.

A full description is given in the paper of the method of setting up the apparatus required for heating the platinum electrically, and for the other purposes, such as photometric comparison with the standard when obtained; and an account is also given of the sources of error, and the investigation which showed the limit of error to be less than 1 per cent. on either side of the true value.

The apparatus, once set up, is in future to be used for reproducing the light unit, and will be the standard of reference for photometric measurements used by the Reichsanstalt.

J. TEICHMÜLLER—THE SPECIFIC CONDUCTIVITY OF COPPER.

(Paper read before the British Association.)

A proposal is made by the author to express the conductivity of copper in units of the electro-magnetic system, dropping altogether the standard hitherto in vogue. At present conductivity is expressed either by comparison with that of pure copper, or in multiples of that of mercury, or in reciprocals of an ohm. The former of these leads to great confusion, as the various determinations of the conductivity of pure copper vary amongst themselves by about three and a half per cent., with the result that some samples of copper have more than 100 per cent. conductivity. Matthiessen's standard, the one most frequently employed, gives the resistance of 100 inches of pure annealed copper wire weighing 100 grains as 0·1516 B.A. ohm at 60°F.; and to reduce this value to international ohms at 0°C., we have to take into account the specific gravity of copper, and its temperature coefficient, both of which are more or less undetermined. being dependent on the mechanical and molecular properties of the copper. Matthiessen himself tried to distinguish between various qualities by giving figures for hard drawn, and soft annealed copper. This method of expressing the conductivity is therefore most unsatisfactory. The method of comparison with mercury is better than the first, but has no relation to absolute measurements. The measurement of the conductivity of copper in reciprocals of an ohm is probably used least of all, possibly because of the want of a name, for the mho is not at all in common use; but corresponding to the megohm centimetre there should be a unit of specific conductivity, the mega-mho-centimetre, which is accordingly proposed by the author

as free from ambiguity and in harmony with the absolute system of measures This unit gives the mhos of conductivity per metre of length and square millimetre of section. The paper was originally read to the "Verband Deutscher "Elektrotechniker."

E. LECHER—A STUDY OF UNIPOLAR INDUCTION.

(*Wiener Ber., July* 12, 1894, *and Phil. Mag., Vol.* 38, *No.* 233, *p.* 424.)

In an abstract of this paper it is stated that the author has divided a magnet equatorially into two parts, each of which can rotate separately, and has obtained by suitable spring contacts an induction current which cannot possibly be due to the cutting of the rotating lines of force in the short spring contacts. The current, says the author, is easily explained if we adopt the view of Faraday, which he afterwards abandoned, that the rotating magnet cuts its own lines of force, and thus has an electro-motive action.

J. DE KOWALSKI—ON THE MIXING OF LIQUIDS.

(*Comptes Rendus, Vol.* 119, *No.* 12, *p.* 512.)

The experiments carried out by the author were for the purpose of verifying a theory developed by Van de Waals, in which it is stated that liquids will mix at certain pressures, provided these be high enough.

The pressure necessary for the following experiments was obtained by means of a screw fitted to a small reservoir, having two observation holes made of quartz, to withstand a pressure of 1,000 atmospheres.

The first experiments were made with a mixture of 9·5 per cent. of alcohol and 90·5 per cent. of water. The mixture became homogeneous at a temperature of 18°. The experiments were, however, made at 15°, compression taking place very slowly, in order not to raise the temperature of the liquid. A pressure of over 1,000 atmospheres was recorded without mixing the liquids. The same negative result was obtained with a mixture consisting of 10 per cent. of ether and 90 per cent. of water, and another consisting of 4 per cent. of aniline and 96 per cent. of water.

In order to increase the mixing power of the liquids, the author had recourse to the following method, devised by M. Duclaux :—A mixture of ethylitic alcohol and (isobutylic) alcohol and water was found to form a homogeneous liquid above 22·4°, and to divide into two distinct liquids at that temperature. The quantities forming the mixture were such that a surplus of (isobutylic) alcohol or of water added to the mixture would have diminished the temperature of separation of the homogeneous liquid into two distinct liquids. In order to make the meniscus of separation more marked, a small quantity of blue colouring matter was introduced, which was soluble in alcohol and insoluble in water. As would be expected, the temperature at which complete mixing took place was raised by the introduction of this colouring matter.

The mixture was next submitted to pressure, temperature being kept constant

at 19·5°. On gradually increasing pressure, a flattening of the meniscus was observed at 600 atmospheres, which became more marked with an increase of pressure. The coloration of the two parts of the liquid gradually equalises, and at a pressure of 880 to 900 atmospheres the meniscus disappears completely and the two liquids mix.

In order to verify that the heat of compression was not the cause of this phenomenon, a pressure of 910 atmospheres was maintained for an hour. The mixture remained homogeneous at a temperature of 19·5°, but on lowering this temperature by 0·5° the line of demarcation became distinct.

These phenomena are very similar to that of a gas below the critical temperature.

The last experiment was an attempt to mix the liquids at a temperature of 19° by increasing the pressure. At a pressure of about 1,000 atmospheres no change was noted in the meniscus. At a pressure of 1,400 to 1,500 atmospheres the quartz pieces were broken, but the liquids remained separated.

These last experiments lead the author to suppose that there exists a temperature below which it is impossible to mix liquids by simple compression.

HENRI MOISSAN—IMPURITIES IN COMMERCIAL ALUMINIUM.

(*Comptes Rendus, Vol.* 19, *No.* 1, *p.* 12.)

Aluminium obtained by the different electrolytic processes is never pure, and its composition is very variable. The chief impurities exist in the form of iron and silicon. The iron comes from the ore, the electrodes, and the crucible. A small percentage of iron is detrimental to the quality of the metal. The silicon also partly comes from the electrodes and crucibles, but chiefly from the aluminium employed. Its presence is more difficult to avoid. Although in many cases its presence is not harmful, it can be considerably eliminated by fusing the metal under a layer of an alkaline fluoride. But apart from iron and silicon there exist two impurities which have not before been mentioned, viz., nitrogen and carbon. When a small piece of commercial aluminium is treated with a 10 per cent. solution of potash, the metal is readily attacked, and the liberated hydrogen contains a small quantity of ammoniacal gases. Absolutely pure potash should be employed for this experiment. When a current of nitrogen is passed through aluminium in a molten condition, the metal shows a diminution in its breaking stress and its elongation.

	Limit of Elasticity.	Breaking Stress.	Elongation.
Cast aluminium	7·500 kg.	11·102 kg.	9 mm.
Aluminium saturated with nitrogen	6·500 ,,	9·6 ,,	6 ,,

The percentage of carbon in commercial brands of aluminium is greater than that of nitrogen. The following figures have been obtained as the percentage of carbon:—0·104, 0·108, and 0·080 per cent. Its presence has a marked effect on the characteristic properties of the metal. Where cast aluminium was found to have a breaking stress of 11·1 kg. and a lengthening of 9 per cent., carburetted aluminium had a breaking stress of only 8·6 kg. and 6·5 kg. and an elongation of 3 mm. and 5 mm. per cent.

These experiments were made on the metal directly after casting. The following figures are after annealing and rolling:—

	Limit of Elasticity.	Breaking Stress.	Lengthening.
Carburetted aluminium	20 kg.	20·793 kg.	2·5 mm.
After rolling and annealing	7·7 ,,	13·3 ,,	26·5 ,,

In conclusion, it is necessary to obtain aluminium as pure as possible, as the above impurities greatly influence its properties.

M. M. C. BERSON and H. BONASSE—ON THE ELASTICITY OF TORSION OF AN OSCILLATING WIRE.

(*Comptes Rendus, Vol.* 119, *No.* 1, *p.* 48.)

The numerous researches which have been carried out on the elasticity of torsion of wires, have been made with the object of studying the laws of torsion under static conditions.

The following experiments were made to ascertain the oscillatory movement of a platinum wire annealed at a red heat, and violently moved from its position of equilibrium:—

During the action of the initial force producing torsion, which lasted about one second 15 photographs were taken at known intervals, and from 10 to 15 extra photographs were taken of the position of the wire during a fraction of the ensuing second. During the first oscillations, from 50 to 100 photographs were taken at known equi-distant periods recorded on an electro-magnetic chronograph; the time of passing through the initial zero being also carefully recorded on the same instrument. The amplitude of oscillation was also measured during a great number of oscillations.

The first general result obtained was the apparent permanent displacement of the zero position. This displacement takes place in the direction of the first impulse, and for any given material it increases—

(1) With the diameter of the wire. The phenomenon is little marked with wires of 0·01 cm. diameter, but with wire of 0·015 cm. diameter the displacement has a value of 35°.

(2) With the maximum acceleration during the action of the first impulse.

It has also been noted that if an annealed wire has received a certain initial impulse, producing a displacement from its zero position, and if after the dying away of these oscillations it receives another impulse, equal to and in the same direction as the first one, the displacement from the zero position will be in the same direction, but much smaller than the last, and with successive impulses these displacements from zero rapidly decrease.

If after a first series of oscillations an impulse is given in the opposite direction, there will be a displacement of the zero in the same direction as the impulse, but weaker than the first, so that the zero will be far from having returned to its original position.

The permanent distortion of the wire existing with very small torsions, as compared to that which corresponds with the static elastic limit, is equivalent to a

considerable loss of energy during the first oscillation, the energy stored in the wire during oscillation tending towards a certain asymptotic value.

M. DESIRÉ KORDA—A TRANSFORMER FOR CONVERTING MONOPHASE CURRENTS INTO TRIPHASE CURRENTS.

(*Comptes Rendus, Vol.* 119, *No.* 1, *p.* 61.)

This apparatus produces a rotating magnetic field of constant intensity by means of a monophase current.

It is designed for the following requirements:—

1. To cause single-phase asynchronous motors to start a full torque.
2. To allow of triphase motors being connected on a single-phase circuit.
3. To act as an ordinary transformer of voltage.

It consists, in principle, of a transformer with three cores, and of a movable self-induction coil, and its theoretical working conditions are as follows:—

The circuit carrying the monophase current, $i = I \sin \omega t$, is divided into two branches, I. and II., having the same ohmic resistance. A self-induction coil is inserted into branch II. in order that

$$\frac{L \omega}{R} = \sqrt{3} = \tan 60^\circ \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

where $\omega = \frac{2 \pi}{T}$ (T being the periodic time).

The current in branch I. may be expressed by—

$$i_1 = \frac{E}{R} \sin \omega t.$$

The current in branch II. is expressed by—

$$i_2 = \frac{E}{\sqrt{R^2 + \omega^2 L^2}} \sin (\omega t - \alpha)$$

$$= \frac{E}{2 R} \sin (\omega t - 60^\circ).$$

That is to say, i_2 will be one-half of current i, as long as equation (1) is satisfied. If the branch II. contains n turns, the branch I. must contain $\frac{n}{2}$ turns wound round the second core, and in opposite directions relatively to one another.

An equal flux will be obtained in each circuit, but having a difference of phase of 240°. And the sum of these turns, wound in opposing direction round the third core, will produce a third flux. By this means three-phase currents can be obtained in the secondary circuits of the transformer. Consequently, by coupling up the three starting ends of these secondary coils, a zero point, 0, will be obtained so long as condition (1) holds good; and this point 0 may be connected by means of a wire to earth, or to the second connection, 0_1, of the secondary coils, without observing any flow of current in that wire. But when the load of the transformer varies, the difference in phase expressed by the left-hand term in equation (1) will also vary equally; for, if

$$s = R + \frac{M^2 \omega^2}{r^2 + l^2 \omega^2} r,$$

$$\lambda = \Lambda - \frac{M^2 \omega^2}{r^2 + l^2 \omega^2} l.$$

where M is the coefficient of mutual induction, Λ the coefficient of self-induction of the primary turns, and l that of the secondary winding, of which r is the ohmic resistance, the difference of phase between the branch circuit and the coil with a self-induction L will be

$$\tan \phi' = \frac{\lambda' \omega}{s},$$

and for the other branch

$$\tan \phi = \frac{\lambda \omega}{l}.$$

And in order to re establish the difference of phase $s' - s = 60°$, it will be necessary to displace the core of the self-induction coil, in order that

$$\tan (\phi' - \phi) = \sqrt{3},$$

which determines a new value for L, and which reduces the potential of the point 0 to zero.

The displacement of the core can be affected by means of an automatic regulator, which would only come to rest when the three secondary currents are quite symmetrical, and consequently when there is no current in the wire 0 0'.

A. PERRIN—THE GRASSOT ELECTRICITY SUPPLY METER FOR CONTINUOUS CURRENTS.

(*Annales Télégraphiques, Vol.* 21, *p.* 243.)

The Grassot meter, constructed by MM. Ducretet and Lejeune, is essentially an ampere-hour or coulomb meter. Its working depends on electro-chemical action, and when current is passing through the instrument it registers continuously.

A carefully drawn silver wire, of equal diameter throughout its length, is placed in a vertical position, its lower end dipping into a solution of nitrate of silver. The wire carries a weight at its upper end, and is guided by a glass tube. The lower end of the wire rests on a glass plate placed a little below the surface of the nitrate of silver. The wire at some distance from its lower end is made to press tangentially against a small drum fixed on the main spindle of the counting gear. The portion of the wire dipping into the solution is gradually consumed by the current, and as the wire descends it causes this drum to revolve, and the number of revolutions are recorded on the ordinary arrangement of dials.

The cathode consists of a silver plate suspended in the solution. The meter is connected as a shunt to a low resistance, R, of German silver placed in the main circuit. The voltameter resistance *per se* is very low; a resistance, r, is placed in this circuit. The current passing through the voltameter will then be $\frac{R}{R + r}$ of the total current. The end of the wire is eaten away by electro-chemical action into the form of a conical point. It may happen that for some reason, such as a violent shock, the end of the wire has become blunt. The needle of the counting train will have moved forward, and will then remain in a fixed position notwithstanding a flow of current through the meter. The conical end of the wire will be re-formed without any alteration to its length until the end has become normal in shape, and the advance of the needle is thus compensated for without producing

any inaccuracy in registration. The advantages claimed for this type of meter are—

1. The absence of mechanism and of magnets, being therefore independent of the variations of a magnetic field, and yielding more constant results. It has no temperature errors.
2. It will work accurately with one lamp.
3. It consumes no current. The amount of silver taken from the wire is re-deposited on the cathode.
4. Its silent working.

M. BELLOC—A NEW METHOD OF PRODUCING THE ELECTRIC ARC.

(*Journal de Physique, Vol.* 3, *p.* 322.)

This method consists in producing an electrostatic discharge between two electrodes connected to the terminals of the source from which the arc is to be obtained. The distance between the electrodes at which the phenomenon takes place depends—

(1) On the polarity of the terminals with reference to that of the electrostatic machine.
(2) On the nature of the electrodes.
(3) On the difference of potential of the source.
(4) On the size of the electrostatic machine.

The following are the maximum values of the sparking gap when the source has a difference of potential of 50 volts:—

Nature of the Electrodes.	Poles. Similar Poles with respect to one another.	Poles. Opposite Poles with respect to one another.
Carbon	0·5 mm.	1 mm.
Copper	1 "	3 "
Zinc...	1·5 "	3·5 "
Copper-zinc ...	—	3·5 "

The arc cannot be produced if the electrostatic machine has no condenser, or if it is replaced by a Ruhmkorff coil. With a four-plate Holz machine the sparking distance obtained has been as great as 7 to 8 mm. with zinc, but the arc could not be maintained. With alternating currents the distance is considerably decreased, and the steady arc is replaced by a number of flashes. In conclusion, it is possible to strike the electric arc in the same manner as gas is lighted by an electrostatic machine.

RAOUL PICTET—EXPERIMENTAL RESEARCHES ON THE EFFECT OF LOW TEMPERATURES ON PHENOMENA OF PHOSPHORESCENCE.

(*Comptes Rendus, Vol.* 119, *No.* 13, *p.* 527.)

The object of these experiments was to determine the specific action, due to a great lowering of temperature, on certain bodies which are luminous in the dark,

after exposure to the solar rays—phenomena known under the name of phosphorescence, and specially studied by Edm. Becquerel.

The first experiments were as follows :—

Glass tubes were taken containing powdered sulphate of calcium, sulphate of baryum, sulphate of strontium, &c. These were exposed to sunlight, and afterwards note was taken as to the amount of light they emitted in the dark, and as to the duration of this luminosity. The tubes were next exposed to sunlight for more than one minute, and were rapidly reduced to a temperature of $-100°$; this process occupying from five to six minutes. On removing the tubes to an absolutely dark room no light whatever was visible to three observers. On allowing the tube to get warm, the top is seen to become luminous, and this effect gradually covers the whole tube, and after five or six minutes it has regained its normal brilliancy without any further exposure to light. This result is general for all phosphorescent substances.

The next experiments were for the purpose of determining at what temperature the phosphorescence of substances ceases to be visible. A trough was filled with alcohol and kept at a temperature of $-75°$. The tubes containing the phosphorescent substances were exposed to sunlight and rapidly immersed in the trough placed in the dark room. The brilliant light of the tube was visibly diminished on immersing in the alcohol, becoming quite invisible when the powder had reached a temperature of $-60°$ or $-70°$.

On removing the tubes from the trough and allowing them to get warm, they were seen, after half an hour, to regain the same degree of luminosity as previous to immersion in the alcohol. These phenomena are general for all phosphorescent substances.

The various coloured lights—such as blue, green, and orange—emitted by the different phosphorescent metallic sulphates all tend to pass to a dull yellow before becoming invisible.

It was conclusively proved that the diminution or final extinction of phosphorescence was in no way due to the moisture and frost which are always present on the surface of bodies at a very low temperature.

It is certain that phosphorescence is due to a certain movement of the particles of the body. The oscillating motions are annulled at low temperatures; luminous waves are no longer set up, and phosphorescence ceases.

GEORGES CHARPY—ON THE TRANSFORMATION OF IRON AND OF CARBON WITH RESPECT TO TEMPERING.

(*Comptes Rendus, Vol.* 118, *No.* 23, *p.* 1258.)

The hardening of steel by tempering has received a good number of explanations, most of them, however, meeting with controversy. The author propcsed to characterise the transformations produced by tempering by making a series of mechanical tests.

A previous series of tests led the author to consider that during the process of tempering there took place an allotropic transformation in the iron. Moreover, it has been known that a transformation takes place in the carbon accompanied,

amongst other things, by a diminution in the coloration produced by dissolving the steel in nitric acid. According to this, Eggertz's colourmetric method would show a weakening of the steel due to hardening.

The author arrives at the following conclusions:—The process of tempering produces, amongst other modifications, a transformation in the iron (characterised by mechanical tests) and a transformation in the carbon (characterised by Eggertz's tests). The first modification seems to have but a small influence on the breaking stress, while the transformation of carbon seems to correspond to an increase in hardness.

M. BIRKELAND—ON THE MAGNETISATION PRODUCED BY HERTZIAN CURRENTS: A MAGNETIC DIELECTRIC.

(*Comptes Rendus, Vol.* 118, *No.* 24, *p.* 1320.)

Two years ago it was conclusively proved by experiment that Hertzian vibrations will travel along an iron wire, magnetising in a transverse direction the very thin layer through which the alternating current travels; the thickness of this layer not being more than a few thousandths of a millimetre.

These experiments led the author to consider whether it would be possible to produce stationary magnetic waves in a magnetic cylinder analogous to the stationary electric waves existing along metallic wires.

Iron could not be used for producing these effects, as its conductivity would be too high, this having been confirmed experimentally.

The author then sought for a material which would be fairly non-conducting, and which would allow the magnetic induction to penetrate sufficiently into the centre.

It was found that a mixture of melted paraffin and iron, chemically reduced to a fine powder, answered the above conditions; the mixture being rendered very homogeneous by the addition of very finely powdered quartz.

The exciter employed in these experiments was such as would produce waves of considerable length. The electrical effect on a spiral of wire placed in the resonator was found to be negligible. This spiral of 12 turns of well-insulated wire, placed in the secondary circuit, receives the cylinders of different materials of which the magnetic properties are to be studied. The spark micrometer, consisting of ball and point, was placed above an adjustable condenser used for adjusting the resonance.

Altogether 12 different cylinders were tested, each one being 20 cm. long and 4 cm. in diameter, and consisted of the following:—

1. A cylinder of solid soft iron.

2. A cylinder consisting of a bundle of iron wires buried in paraffin.

3-9. Six cylinders consisting of a mixture of reduced iron and paraffin, containing respectively in volume the following percentages of iron:—5, 10, 15, 20, 25, 50.

10. A cylinder consisting of a mixture of fine powdered zinc and paraffin, there being 40 per cent. by volume of zinc.

11. A cylinder consisting of strip brass and paraffin, there being 20 per cent. of metal

12. A glass tube, 4·5 cm. in diameter, to be filled with electrolytes of different conductivities.

The method of observing was as follows:—

The resonator, with its empty spiral, was put in resonance with the exciter, and the maximum length of spark was measured, being during these experiments from 4 mm. to 9 mm. long. The cylinders 1–12 were then introduced, one after the other, and the length of spark measured in each case. The cylinder 1 made practically no difference. Cylinders 2–4, however, reduced the secondary spark to 1-10th of its initial value; Nos. 7 and 8 to 1-100th of this value; and No. 9 to 1-200th (from 9 mm. to 0·05 m.). Cylinders 10 to 11 produced but a feeble action, the reduction being from 8 mm. to 7 mm. Tube 12 was filled with distilled water and did not sensibly alter the spark; while with a solution of sulphuric acid of 10, 20, and 30 per cent. the reduction was the same in each case—from 9 mm. to about 1·3 mm.

In attempting to re-establish the resonance between the primary and secondary after the introduction of one of the cylinders, it was found that the period of the resonator was considerably increased by the presence of cylinders 2 and 4, but the length of spark was considerably diminished.

It was impossible to establish unison when cylinders 5–9 were introduced in the spiral, pointing out that the iron and paraffin cylinders absorb much energy, being probably due to hysteresis. It was no doubt absorption that prevented the stationary magnetic waves from being observed.

In order to ascertain to what depth magnetisation took place in the iron and paraffin, the cylinders were made hollow, and into which a solid cylinder could be introduced.

The presence of one of the hollow cylinders caused a marked diminution in the spark, which was magnified by the introduction of a solid cylinder in the first one.

It was found in this way that the magnetisation easily penetrated to a depth of 7 mm. in a 10 per cent. iron paraffin cylinder, and to a depth of 5 mm. in a 25 per cent. cylinder.

A. BARBARET—TELEPHONIC CABLES WITH DRY AIR CIRCULATION.

(*Annales Télégraphiques*, *Vol.* 21, *May–June*, *p.* 193.)

Telephone cables used for a long time past in Paris consisted of gutta-percha-covered wires protected with a covering of lead. Although modifications have been made from time to time, the following specification practically holds good:—

The cable consists of seven pairs of wires, each wire consisting of three strands of copper 0·5 mm. in diameter, and covered with gutta-percha to form a diameter of 3 mm.

The seven pairs are laid up together to form a cable, which is then covered with cotton tape, and finally with a lead covering 1·25 mm. thick. The external diameter of the cable is 22 mm. The weight per kilometre is 1·070 kilogrammes, and the length of each section is 500 metres. The ohmic resistance of each conductor is 31·22 ohms at + 24° C., and the insulation resistance per kilometre varies

between 200 and 2,500 megohms. The capacity per kilometre is 0·25 microfarads. These cables are easily laid, on account of the flexibility, and a faulty section can be replaced with facility.

Owing to the thinness of the lead covering, these cables do not last for more than 8 or 10 years underground. Their cost is about 3,240 francs per kilometre, and is largely dependent on the price of gutta-percha. The main disadvantage of these cables is their high resistance and capacity, which renders them useless for long-distance telephony. It would be comparatively easy to diminish the resistance, but the capacity cannot be varied much, as this depends on the specific coefficient of gutta-percha.

For long-distance telephony Fortin-Hermann cables are largely employed, on account of their low capacity. The core consists of seven strands of 0·7 mm. or of 0·5 mm., on which are threaded a number of paraffined wood beads, in the form of cylinders, 8 mm. long and 4 mm. in external diameter. The wires are finally protected with an envelope of lead 3 mm. thick. The external diameter of the cable is 29 mm., the length of each section 200 metres, and the ohmic resistance of each conductor 13 ω at 124° C. The insulation resistance per kilometre is 1,000 megohms, and the capacity is 0·06 microfarad per kilometre; the figures obtained in general practice being better than the above specified figures. The insulation resistance depends on the dryness of the air in the cables.

The joints between the sections are made by means of ebonite sleeves having 14 grooves round the periphery into which the conductors are joined. This sleeve is then covered by means of a cylinder of ebonite in two halves, the whole joint being protected by a lead sleeve soldered to the ends of the cable.

These cables are fairly easy to lay, and the insulation resistance is easily maintained so long as there is no fault in the lead covering. Such a fault can be remedied by the process described below, and which is employed during the manufacture and the laying of Fortin cables, and also of paper- and cotton-insulated cables.

At the end of 1891, a Fortin cable used in Paris between the "Bourse" and the "Gare Montparnasse" had become defective, owing to portions of the lead covering having been eaten away by rats. This admitted moist air into the cable, and the insulation resistance fell to 1 megohm per kilometre. The hole in the lead covering was soldered up, but it was ascertained that in order to raise the insulation resistance to 100 megohms would necessitate the renewal of several sections. It was then thought that by removing the damp air the insulation resistance could be restored to its original value of 5,000 megohms.

A desiccator was employed consisting of two glass tubes containing 3·5 kilogrammes of sulphuric acid, and of a large tube with chloride of calcium at the top and with lime at the lower part; the lime being used for arresting all acid vapours. A water pump was employed as an aspirator, and, notwithstanding the ebonite plugs used at every joint of the cable, a gentle flow of air was obtained through a length of 5·2 kilometres. The insulation resistance had been much improved in this manner, when by accident some water from the pump was admitted into the cable.

This water was forced out by producing a pressure of 8 kilogrammes per square

centimetre at one end, and a vacuum of 6·6 kilogrammes per square centimetre at the other end. A current of dry air was next passed for 88 hours. The insulation resistance was then found to be 600 megohms per kilometre in the section which had received the water. During this experiment the flask of sulphuric acid had increased by 600 grammes in weight. The insulation resistance was finally brought up to 12,500 megohms per kilometre, being better than when first laid.

As the ebonite plugs used at every joint were found to offer too much resistance to the passage of dry air, a hole of 8 mm. in diameter was eventually drilled through the centre of each plug.

The circulation of dry air in connection with these cables is now always obtained by pressure, and not by vacuum; there being the advantage of more easily localising the leak in the lead covering, and of not drawing in moist air if there exists such a leak.

This process is also employed for paper- or cotton-insulated cables, it being necessary in this case to employ a higher pressure in order to cause the air to circulate.

The latest form of desiccator consists of six iron cylinders 5 mm. thick, 200 mm. in external diameter, and 1·20 metres high, closed at the ends by iron plates bolted to a flange. A grid is placed in each cylinder at a height of 0·2 metre from the bottom, and all the upper part is filled with chloride of calcium (about 30 litres per cylinder).

Each cylinder stands on an oak box, and is fitted at the lower end with a tap, for the purpose of running off any dissolved chloride of calcium. The last cylinder is not quite filled, a height of about 0·3 metre being packed with cotton wool, in order to filter the air of any dust.

The necessary pressure is obtained from the Popp Supply Co.* at 5 kilogrammes per square centimetre; as this is too high, a reduction valve is employed for reducing the pressure to about 3 kilogrammes.

All cables insulated with cotton or paper, without paraffin or other insulator, can be subjected to the above treatment, as was shown during tests on Fowler-Waring and Felten & Guillaume cables; the condition being that no obstruction should be offered at the joints to the flow of air, somewhat modifying the system of soldering the joints.

The author shows that the great advantage of this system is that a fault in the lead covering can be repaired without interruption to the service by merely circulating dry air through the cable, and soldering up the hole after having brought up the insulation resistance to the desired standard.

In the manufacture of Fortin cables, a current of air is forced through the cable during the process of lead-covering when the cable is hot. By this means an insulation resistance of 10,000 megohms per kilometre is easily obtained.

In the manufacture of such cables it does not matter much under what form the cellulose is used—whether as paper, wood, or cotton—as the dielectric consists really of dry air; these materials being only used as a mechanical separation between the wires. For the sake of economy paper could advantageously take the place of the wooden beads, and is less hygroscopic than cotton. The thickness

of the lead covering should never be less than 3 mm.; for cables with 27 pairs of conductors the thickness should be 3·25 mm.; and for cables with 51 pairs 3·5 mm. should be the minimum thickness.

It is advisable to protect lead-covered cables from the chemical actions of the soil by surrounding them with bitumen.

Air-insulated cables can also profitably be employed in telegraphy, although their capacity is not sufficiently high to prevent the effects of induced currents in cases where earth returns are employed. But by the use of a copper return these induced effects can be entirely eliminated, and great advantages obtained where rapid transmission is a consideration. These double-circuit cables would be cheaper than single-circuit cables insulated with gutta-percha.

The author considers that air-insulated cables could also be advantageously employed for electric lighting and transmission of power.

P. JANET—AN ELECTRO-CHEMICAL METHOD FOR AUTOMATICALLY RECORDING PERIODIC CURRENTS.

(*Comptes Rendus, Vol.* 119, *No.* 3, *p.* 217.)

The author has previously described an electro-chemical method of constructing a curve representing a periodic current, which was, however, not a direct method.

The present improvement consists in directly describing the curve on the registering cylinder. The apparatus consists of 15 styles (darning needles) insulated from one another, and of which the points are placed in a straight line and separated by a distance of about 1 millimètre. These styles are respectively connected to 15 equi-distant points of a battery of accumulators connected in series, there being about 4 volts difference of potential between two consecutive points. If A and B be the two points across which it is desired to study the periodic electro-motive force, the point A is placed in communication with the cylinder, and the point B with one of the styles. It will then be found that each style describes a number of blue lines on a white ground in the form of a curve. The author showed curves obtained by the above method, and representing the difference of potential at the secondary terminals of a Zipernowsky transformer.

By this electro-chemical method the most important points in connection with alternating currents can be studied, viz.: frequency, difference of phase, form of current and electro-motive force curve; and, although perhaps not so accurate, this method should find its place beside others which are far more delicate and complicated.

C. E. GUYE—THE COEFFICIENT OF SELF-INDUCTION OF *n* WIRES, PARALLEL AND EQUI-DISTANT, AND OF WHICH THE SECTIONS ARE [LAID] ROUND A CIRCUMFERENCE.

(*Comptes Rendus, Vol.* 119, *No.* 3, *p.* 219.)

In order to experimentally verify certain formulæ, the coefficients of self-induction of two systems were determined. The first one consisted of three wires,

each 0·007015 cm. in radius, the section of the system consisting of three equi-distant circular surfaces placed on a circumference of 50 cm. radius.

The second analogous system consisted of six similar wires. The method employed was one well adapted for the measurements of small coefficients of self-induction. In consists in observing the extinction of sound in a telephone connected across the diagonal of a Wheatstone bridge; the other branches consisting of the conductor in question and of known resistances; the battery being replaced by the secondary of an induction coil. The apparatus also consists of a variable mutual induction, formed of two coils, movable with respect to one another. One of the coils is placed in the diagonal of the telephone, and the other in the branch containing the electro-motive force. By the suitable manipulation of resistances and of the variable induction all sound in the telephone can be annulled, and the required figures obtained for determining the coefficient.

If the six resistances be called r_0, r, r_1, r_2, r_3, r_4, and their coefficients of self-induction L_0, L, L_1, L_2, L_3, L_4, and M the coefficient of mutual induction of the movable coils, then the coefficient L can be expressed as follows:—

$$L_1 = M\left(1 + \frac{r_1}{r_2} + \frac{r_1}{r_3} + \frac{r_1}{r_4}\right) + L_2 \frac{r_1}{r_2} + L_3 \frac{r_1}{r_3} - L_4 \frac{r_1}{r_4}.$$

And in choosing for r_3 and r_4 similar conductors the expression is reduced to—

$$L_1 = L_2 + M\left(2 + 2\frac{r_1}{r_2}\right),$$

the conductor 2 being a wire wound back on itself. After making all corrections, this method yielded the following results:—

1st System.	2nd System.
$L_1 = 4{,}704$ cm.	$L_1 = 4{,}155$ cm.

The coefficients were next calculated by the following formula giving the mutual potential between two linear parallel circuits:—

$$m = 8\left[b \log_e \left(\frac{b + \sqrt{b^2 + d^2}}{b + \sqrt{2b^2 + d^2}} \frac{\sqrt{b^2 \div d^2}}{a}\right) + 2\sqrt{2b^2 + d^2} - 2\sqrt{b^2 + d^2} + d\right]$$

By replacing in this expression the mean geometric distance, a, of the elements forming the section, for the distance, d, between the conductors, one obtains the required coefficient. The mean distance, a, is, in this particular case, given by the formula,

$$\log a = \frac{\log (a_1 n R^{n-1})}{n},$$

in which a_1 represents the mean distance of the elements of the section of a single wire (0·7788 s), n the number of wires, and R the radius of the circumference on which lie the sections of the different wires.

The figures are—

For the First System.	For the Second System.
$a_1 = 0·005463$ cm.	$a_1 = 0·005463$ cm.
$n = 3$	$n = 6$
$R = 0·50$,,	$R = 0·50$,,
$a = 0·1600$,,	$a = 0·3175$,,
$L'_1 = 4{,}656$,,	$L_1 = 4{,}132$,,

The difference between the results of calculation and of experiment is between 1-100th and 1-200th.

P. BEULARD—ON THE SPECIFIC INDUCTIVE CAPACITY OF GLASS.

(*Comptes Rendus, Vol.* 119, *No.* 4, *p.* 268.)

To measure the specific inductive capacity of glass presents special difficulties, which accounts, perhaps, for the large difference between the results of different observers.

The author studied specially the effect of time of charge, and also the value of the specific inductive capacity of glass for a time of charge equal to zero. The ballistic method was employed, and consisted in discharging the condenser with or without glass through the galvanometer. It is necessary to make corrections for the damping action of the galvanometer, which may become appreciable.

The condenser employed consisted of rectangular wooden plates covered with tinfoil and separated by ebonite. To eliminate the effect due to the edges the method suggested by M. Blondlot was employed.

If A be the capacity—in electrostatic units (G.S.)—of the air condenser, B the capacity of the same condenser with a glass plate, and x the correction for the edge action; if E be the thickness of the separating pieces, e the thickness of the glass plate less than the distance between the wooden plates by an amount $\epsilon = E - e$, and S the effective surface of the plates, then

$$x + \frac{S}{4 n E} = A; \quad x + \frac{S}{4 n}\left(\frac{1}{\frac{e}{k} + \epsilon}\right) = B \quad \ldots \quad \ldots \quad (1)$$

where k is the specific inductive capacity.

By eliminating x,
$$k = \frac{1 + (B - A) C e}{1 - (B - A) C \epsilon} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

and by substituting,
$$C = \frac{4 n}{S} \frac{E}{e} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

The time of charge varied between 1-50th and 1-800th of one second.

The results were plotted in the form of a curve having the values of time as abscissæ, $0x$, and deflections of the galvanometer as ordinates, $0y$. The curve relative to glass starts from the origin, rises rapidly, and then bends, presenting its concave side to the axis $0x$; it then becomes rectilinear, but this portion of the curve is not parallel to the axis $0x$ on account of the conductivity of the ebonite separating pieces. The projection of this line would cut the vertical axis, $0y$, at a certain point, corresponding to a deflection, D, obtained in working during a time of charge equal to zero.

$$B \times v = g \frac{\tau}{2\pi} D \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

where v represents the potential of the charge, and $g \frac{\tau}{2\pi}$ the ballistic constant; and for the air condenser,

$$A \times v = g \frac{\tau}{2\pi} D' \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

k can then be calculcated by formula (2).

An Atwood's machine was employed for varying the time of charge.

The mean of a number of results gave to k the value 3·9.

The curve of charge as a function of the time allows of an important theoretical verification.

If E is the electro-motive force of the battery, v the potential of the collector, and C the capacity of the condenser, R the resistance of the circuit, and Q the charge at the time t, then

$$C R \frac{d v}{d t} + v = E; \; i = \frac{d Q}{d t} = C \frac{d v}{d t} \quad \ldots \quad \ldots \quad (6)$$

yielding this relation— $$\frac{d Q}{d t} = \frac{I}{C R} (Q - C E) \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

$Q - C E$ is found from the curve, and also $\frac{d Q}{d t}$, which is an angular coefficient of the tangent to the curve. It is then possible to verify very exactly that the quotient, $\dfrac{Q - C E}{\frac{d Q}{d t}}$, is a constant.

L. THOMAS—ON THE CONSTITUTION OF THE ELECTRIC ARC.

(*Comptes Rendus, Vol.* 119, *No.* 18, *p.* 728.)

The production of interference fringes by the light from the electric arc shows that a region close to the negative pole is sensibly monochromatic.

By illuminating simultaneously one half of the field with the arc light, and the other half from a flame charged with sodium, the two series of fringes were seen to agree exactly. The phenomenon is attributed to the great brilliancy of sodium vapour, in the neighbourhood of the negative pole, relatively to the other gases present. The vapour is known to pass from the negative pole to the exterior flame.

The spectroscope was used to ascertain whether the accumulation at the negative pole was characteristic of sodium only.

In experimenting, the author followed the same lines as Mr. Lockyer had done previously, special note being made of the following two points:—

1. A modification in a spectrum line can only be referred to a particular region of the source of light, so long as the image of the source is being projected on the plane of the slit, and the spectroscope supplies a linear spectrum for each point of the slit; an aplanatic adjustment is therefore necessary, as described by M. Cornu.
2. In order not to be influenced by the frequent modifications of the arc, it is necessary to reduce the time of observation to the shortest possible amount, which is effected by photographing the regions most sensitive to the plate.

Ordinary carbons were employed, containing such impurities as iron or calcium; carbons were also used with a core consisting of a mixture of powdered carbon and a metallic salt. If the proportions of the latter be not too great, and the two are well mixed, these carbons will yield very constant results. The following notes were made:—

1. With the slit parallel to the carbons and dividing the arc into two equal parts, the metallic lines were seen through their whole height, and increased in brilliancy and in width from positive to negative, the rate of increase being very great when nearing the latter.
2. With the slit parallel to the carbons, outside the brilliant zone which terminates the negative carbon, the spectrum is divided into two parts

situated at different levels. Close to the negative carbon are observed the Swan spectrum and cyanide spectrum, and beyond is seen the spectrum of metallic vapours, presenting its maximum effect at about the level at which the fine lines of the former terminate.

3. With the slit perpendicular to carbons, the metallic rays extend much farther than the spectrum lines. The latter decrease in width from the centre to the extremities, irrespective of the position of the slit between the two carbons. The metallic lines have the same shape in the neighbourhood of the negative carbon, but elsewhere they have a constant width, excepting the narrowing at the extremities. It is therefore easy to account for the frequent change which occurs from one moment to another when the spectrum is directly observed.

Outside the arc, and principally in the neighbourhood of the negative pole, are observed spectra of metallic oxides, the barium and calcium bands being specially brilliant. This is accounted for in the following manner:—The arc, formed between two carbons containing metallic salts, consists of a core and of an envelope. Within the core are substances which emit spectra of bands—carbon vapours and cyanogen; in the envelope, circulates the carbon from positive to negative, also metallic molecules which are transported to the negative carbon and combine with the oxygen of the air and escape.

The above explains the difference in shape and brilliancy of the two poles.

The arc may be looked upon as a sort of gas voltameter. The positive carbon is attacked by the gas which carries the current; the negative carbon is protected against the access of air by the metallic vapours.

In very rarefied atmosphere, the parts of the arc at each of the two poles are almost similar; in hydrogen, under a pressure of about 10 centimetres, the brilliancy is greatest from H_α to H_β in the neighbourhood of the negative pole. In ordinary coal gas, in one hour there forms a large and regular deposit of compact carbon; the negative carbon shows a large number of craters.

If the positive carbon be coated with chloride of strontium, the arc is only stable when the negative carbon is shaped into a cylinder of small diameter with a rounded end.

CLASSIFIED LIST OF ARTICLES

RELATING TO

ELECTRICITY AND MAGNETISM

Appearing in some of the principal Technical Journals from JUNE to NOVEMBER, 1894.

S. denotes a series of articles. I. denotes fully illustrated.

ELECTRIC LIGHTING AND POWER.

ROESSLER and WEDDING—On the Pressure and Current Curves of various Types of Alternators, and their Influence on the Illuminating Power of the Alternate-Current Arc Lamp.—*E. T. Z.*, 1894, No. 23, p. 315 (I.).

ANON.—The Electric Power Transmission from Laucherthal to Sigmaringen.—*E. T. Z.*, 1894, No. 26, p. 354 (I.).

— VASCHY—On the Method of Transformation of Work into Electric Energy.—*C. R.*, vol. 118, No. 23, p. 1249.

G. CLAUDE—Questions relating to the Three-Wire System of Distribution.—*Lum. El.*, vol. 52, No. 22, p. 401, No. 23, p. 471 (I.).

G. RICHARD—The Mechanical Applications of Electricity.—*Lum. El.*, vol. 52, No. 22, p. 416; vol. 53, No. 27, p. 15 (S. I.).

ANON.—The Lighting of the Large Hotels at Ragatz.—*Lum. El.*, vol. 52, No 22, p. 435 (I.).

F. GUILBERT—Transmission of Electric Energy from La Chapelle to Épinay.—*Lum. El.*, vol. 52, No. 24, p. 501 (I.).

ANON.—The Seger Steam Turbine.—*Ibid.*, p. 529 (I.).

G. RICHARD—Arc Lamps.—*Lum. El.*, vol. 52, No. 25, p. 562; vol. 53, No. 29, p. 108 (S. I.)

K. SOSNOWSKI—The Laval Steam Turbine.—*Bull. Soc. Int.*, vol. 11, No. 108, p. 228 (I.).

P. MARCILLAC—The Lifts at Notre Dame de la Garde, Marseilles.—*Lum. El.*, vol. 53, No. 27, p. 28 (I.).

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G. CLAUDE—The Halles Central Station.—*Lum. El.*, vol. 53, No. 28, p. 51, No. 29, p. 114, No. 30, p. 164.

ANON.—The De Bovet Machinery utilising Magnetic Adherence.—*Ibid.*, p. 75, No. 29, p. 127, No. 30, p. 178 (S. I.).

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